Industrial Progress

IN

GOLD MINING.

A REVIEW

OF THE

Gold Mining Industry in the United States.

WITH APPENDIX AND NOTES.

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PREFACE.

The presentation of this volume to the public interested in mining for the precious metals will excuse the absence of a prefatory attempt to harmonize realization with expectation.

The work is without pretension, and is yet not inutile, either in facts or the burthen of information. Confessedly, on all sides, the subject is one of great commercial importance.

The development of a serious default in the customary methods of beneficiating ores for the precious metals, when followed by the commendation of a remedy as comprehensive as the default is universal, must interest a large class of inquirers and intending investors. In this view the Mears Chlorination Company regard INDUSTRIAL PROGRESS IN GOLD-MINING as a very valuable *résumé* of the present condition of the industry. They are persuaded readers will agree with them in this opinion, especially after perusing the articles discussing the treatment of auriferous sulphides and the causes of waste in manipulating ores, which contain these as the most abundant source of auric wealth—the characteristic ores in the rocky areas of the precious metals. If right in this supposition, thanks are due to the author for so much useful work in a new direction and to the Company for presenting the result in the acceptable form of the present volume.

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INDUSTRIAL PROGRESS IN GOLD MINING.

ARTICLE I.

GOLD FINDING IN THE UNITED STATES.

THREE auric tidal waves, if the expression is permissible, have overspread the Atlantic States at irregularly separated intervals, each hastily flowing to the full and slowly ebbing. These were severally characterized by the ephemeral excitement arising upon newly-published discoveries. The incoming of the fourth differs in this respect, bringing with it the conservative influences which betoken permanency. A reflux or retrocession is not probable.

FIRST PERIOD.—In 1799 there was found in Cabarrus county, North Carolina, a golden nugget of great value. In 1825 the pioneer prospector, Matthew Barringer, made the first "discovery" of vein quartz in the United States. In 1830 Georgia was credited in the United States mint with the important deposit of $212,000. Public interest, previously aroused, now rapidly verged to a condition of excitement most unusual in those early days of stage-coach, weekly papers, and fortnightly mails. The sparse population, great distance, and inadequacy of transportation, added to a total want of experience in methods or machinery, narrowed mining investments and caused some misadventures. Before the announcement of

the California discoveries no important vein-mining had been done, and very little gold won outside of gravel diggings.

Second Period.—The second wave or period of interest dates from 1848. California was once a Spanish possession. Legends of fabulous wealth obtained from Spain's distant colonies quickly fired the public mind, and it was easy to relocate or centre all of them in the Eldorado on the Pacific coast. A tumultuous rush was made overland and around the distant Cape Horn. The changes wrought and forces accelerated in the decade following will, for all time, mark that date as the opening of a new era—a departure from the repressive control of slow routine and steady custom, growing unyielding and obdurate by time—a second exodus, as that of Plymouth Rock, revealing a new and an expansive future for every purpose involved in human progress. But a lesson in caution had already taught abstinence. The Atlantic centres of finance and commerce preferred to be represented in gold mining chiefly through the more profitable commercial and trade dependence of the far West, thereafter to be supported, indefinitely, as was then supposed, in population, merchandise, and material from the East. Scarcely a company organization was formed in the "States" upon the ownership of a California mining property. In London and Paris it was otherwise. The capitalists of Boston, New York, and Philadelphia had not yet become sufficiently cosmopolitan.

Third Period.—The return period came again in 1858, when, five years after, a third excitement had grown into an epidemic, quickened through the former abstinence, and intensified by an existing plethora of war currency. Business men, financiers, professional men, and trades-people of all classes, ignored the commonest maxims of trade wisdom and prudence. From twenty to thirty millions of United States currency were speedily converted into one hundred and thirty to forty mil-

lions, in printed shares, mostly representative of property within and machinery for only one county in Colorado.* An abundant crop of failures soon followed. No experience had been gained in operative mining in the South, and only distantly theoretic with regard to California. Eastern investors then knew literally nothing of miners, mines, or mining. A knowledge of all three has been found to be essential to a successful management.

FOURTH PERIOD.—Public attention in the Atlantic States is again directed to the winning of the precious metals, now in an industrial and conservative sense. Vast stores of information upon mining affairs have been accumulated, notably in Raymond's Reports (69 to 77), in mining journals ably edited, and in various scientific publications. Mining schools, home and foreign, have educated American mining engineers and experts. Methods of working ores have been greatly progressed, the needed machinery cheapened and improved. In the meanwhile a superficial area of metalliferous deposits has been partially explored in fifteen States and Territories, and sufficiently prospected to show the existence of the precious metals to be inexhaustible in centuries, however stupendous may be the outlay of capital and energy.

This return of confidence in mining affairs, after the breakdown following the failures in Colorado, is based on reflection and mainly due to a conviction, slowly acquired, that purely speculative mining—mining in shares at the exchange—is extremely hazardous; that the purchase of undeveloped mines in periods of mining furore, at fabulous prices, is unwise, if not unsafe; that capitalizing companies at millions and selling twenty-five-cent shares to get the working capital may not be legitimate—convictions which have crystallized into logical conclusions in favor of an industry that has lived through the

*See Note No. 1.

most oppressive exactions of speculation, inexperience, and misrepresentation, and has, notwithstanding, expanded to prodigious proportions, gathering to itself, in spite of every obstacle, irrefutable proof of large profits, stability, and indefinite scope for future expansion. Surely, it would have been marvelous if such views had not been reached sooner or later. The earth is the source of all wealth to individuals and nations. The soil of itself, town lots and city fronts, would be of no more worth per acre or per foot than Indian reservations in the Rocky Mountains, in a commercial sense, were it not for the minerals in the earth. Without coal, iron, copper, lead, silver, and gold, and the need of science, industry, and invention for their utilization, the Bedouin of the desert, and the Indian would represent the highest types of civilization. Strange then it would be—with reference to the financial centres of the east, or with regard to the financing of company organizations—if the winning of the noble metals, the concrete of all values, should remain subject to speculative devices, only to be acquired by luck, chance, or gambling, or to be wrought from the earth by means and methods needing neither experience, prudence, nor honest management.

ARTICLE II.

THE WORLD'S ACCUMULATION OF PRECIOUS METALS—1878.

Gold and silver were used as money in very early times, either of Hindoo or Egyptian origin, somewhere about 3000 B. C. Cadmus and Jason, both Phœnicians, are credited, in legendary lore, the first as the pioneer quartz miner, the second as the original prospector. About 1594 B. C. the former is said to have opened "a copper and gold mine" (auriferous sulphides) in Thrace, and carried thither his alphabet and spelling books—probably the origin of "honest miner." Jason, of poetical memory, as the man of the "Golden Fleece," 1263 B. C. left Thessaly in a fifty-oared barge to make a prospecting tour of considerable extent.

The several rulers of Phœnicia, Phrygia, and Lydia, among whom Midas, Crœsus, and Pytheus may be termed the "Bonanza kings" of their times, acquired immense treasures, both by mining and spoliation. The latter of these was conquered by Xerxes, of Persia, and relieved of some $18,000,000. Darius III. of Persia, 500 B. C., conquered and plundered Bactria, Asia Minor, the Greek Island, Thrace, Egypt, and Phœnicia, and thus came into possession of the whole store of bullion then gathered up, also nearly all of the mining countries then known outside of India. The next great movement of bullion occurred when Alexander the Great plundered Persia and the surrounding nations, thus forcibly acquiring from $250,000,000 to $300,000,000. It was then he became lachrymose,—"no more worlds" of bullion "for him to conquer."

In the course of time Carthage became the centre of great mining operations in Egypt, Spain, and the Islands of the Mediterranean. This continued for several hundred years, filling the city of Dido with immense amounts of bullion. The next movement was about 146 B. C., when Carthage was cap-

tured and her treasury removed to Rome. During this while the Romans extended their conquests in all parts of the ancient world and gathered into Rome, under Marius, Sylla, Pompey, and Cæsar, nearly all the gold and silver then held in a shape to be plundered and removed. Rome became the treasury or storehouse of the world's riches in bullion. By A. D. 476 the Huns, Goths, and Vandals accomplished the final movement, previous to the middle ages, by distributing the acquisitions gathered in Rome.

Discovery in America.—The greatest movement of the precious metals awaited the turgid course of a thousand years of almost universal confusion in Southern Europe. Rome, through her most valiant generals, had given permanency to the fundamental laws of conquest, as illustrated by their predecessors in history, Darius of Persia, and Alexander of Macedon—"plunder, tribute, and spoliation." The plunder of Rome enriched the conquerors—internecine strife, predatory warfare, and indiscriminate robbery, subdivided the spoils. The earth was but rarely tasked to furnish additional supplies. In the meanwhile, Venice, by the Adriatic, had risen to commercial power. In the twelfth century she controlled the flow of the precious metals by trade with the Orient, mostly gold in exchange for silver of western production. Minting was established, but the supply of gold was insufficient for the demands of trade. The accumulation of two thousand years had been dispersed and divided among feudatory chiefs and savage barons, far removed from traffic. Genoa had also grown into power sufficiently to contest the supremacy of Venice. The Levantine trade had educated mariners and taught the art of ship-building for venture on the ocean. Christopher Columbus, a Genoese, had already voyaged to the Azores and the coast of Iceland. With rare intelligence and the clairvoyance of an enthusiast, he conceived the bold idea of solving the ancient problem—going westward to reach the Orient—the spheroidity

of the earth, an Aristotleian suggestion for reaching the Indus by going west from the Pillars of Hercules,—no conception then of the distance. No one yet had made the venture, and the Cape of Good Hope had not been doubled. The thoughts of eighteen hundred years on this subject, crystallized in the mind of Columbus, inspired with golden visions. To reach Cathay, Chrysé, Zipangu (Japan), and India—to solve the problem and open up by sea a wider channel for the inflow of the coveted wealth of those golden lands—to rebuild a second magnificent Carthage, re-establish a new Rome, and again erect a central power to domineer the world through accumulation of gold, were, in part, the dreams of Columbus. The power of Genoa was diminished, the trade of Venice was threatened, Levantine commerce had narrowed. Columbus visited Lisbon (1470), then gaining renown for commercial emprise and maritime excursion, through the royal patronage of John II. of Portugal. Intrigue averted the friendly disposition of the king, and Columbus carried his proposals to Ferdinand and Isabella of Spain. After twenty odd years of labor success was achieved.

With royal help, in small degree; with more liberal aid from the private purses of two financiers, Columbus obtained an outfit to reach the Orient and carry back some of the golden treasures of the Indus. One-eighth of the metals (gold and silver), gems, and merchandise, was to be his compensation in addition to the supreme command. When off the hazy but lovely shores of Cuba, in the belief he was already viewing the southern shore of Eastern Asia, the infatuated mariner journalized his thought—"from the great heat which I suffer the country must be rich in gold." Having landed on the Queen of the Antilles, the first queries were for gold. Leaving a guard in possession, the first troubles arose from a marauding expedition to the interior in search of the treasure.

Columbus retained his convictions of having reached the East Indies, and hence the geographical title "West Indies."

The new movement of the precious metals from the West to the East was inaugurated.

Expeditions followed each other. Cuba, San Domingo, Darien, Yucatan, Guatamala, and countries down the Pacific coast from Panama, were overrun by the Spanish gold seekers, who took all the natives had and forced them to work the mines for more. Brazil was discovered in 1500 and gold in 1577. One hundred years passed (1680) before mining produced beyond $1,000,000. About 1518 Hernandez Cortez sailed from Cuba on a gold-seeking expedition to Central America and Mexico, landed at Tobasco, overrun the country, treacherously imprisoned Montezuma, captured the city of Mexico, and plundered the people, cities, and villages of all the gold, silver, and other treasures, and thus Mexico was brought into activity as a silver-mining area—the greatest then or since known.

Production up to 1878.

	Gold.	Silver.
From 1493 to 1800 America furnished	$1,965,600,000	$3,726,300,000
From 1801 to 1878 America and all the world furnished	4,153,200,000	2,777,500,000
	$6,118,800,000	$6,503,800,000
Total gold and silver up to 1878		$12,622,600,000

In this total calculation—

All United States,	from	1848	$1,319,481,665
Australia,	"	1851	1,200,000,000
Brazil,	"	1680	900,000,000
Russia,	"	1784	820,271,000
Japan,	"	1545	517,000,000
All other countries	"	1848	324,000,000
Colorado (calculated in above)		1859	75,000,000
* From 1776 to 1847 the United States is credited with..			200,000,000

* A. Delmar's "History of the Precious Metals" furnishes the data for almost all of the above totals.

Recent Annual Production of the Precious Metals.

		Gold.
Present annual production of the world..........		$130,000,000
United States..........	$55,900,000	
Australia..........	31,200,000	
Russia..........	15,600,000	
All other countries..........	27,000,000	
		$130,000,000
		Silver.
Whole product of the world..........		$80,000,000
United States..........	$38,000,000	
All other countries..........	42,000,000	
		$80,000,000
Total yearly product of the precious metals..........		$210,000,000

Article III.

THE AREAS OF GOLD DISTRIBUTION.*

Gold, in a physical sense, is very widely distributed over the globe in soil and organic matter, which often show minute traces, but in a geological sense, and in notable quantity, it is only found, as heretofore indicated, in somewhat defined geological formations.

The Gold Regions of the Old World were extensive—Great Britain, Ireland, France, Spain, Portugal, Switzerland, Russian Possessions, Germany, Austrian Empire, Central and Southern Asia, China, Japan, and Africa, or those portions of the world thus geographically described in modern days.

"In Modern Europe it is yet found sparingly in Cornwall and Devon, England, North Wales, Scotland, and Ireland, formerly in the county of Wicklow, where a nugget of twenty-two ounces was found, and in France very sparingly in the

*See Appendix, page 86.—Prof. Blake's calculation for percentage of production of the Gold Areas of the World.

department of Isère; in the sands of the Rhine, the Reus, and the Aar; in Tyrol and Salzburg; on the southern slope of the Appenine Alps, from the Simplon and Monte Rosa to the valley of Aosta, Northern Piedmont, where six thousand ounces were obtained in 1867; more abundantly in Hungary, at Königsberg, Schemnitz, and Felsobanya, and in Transylvania at Kapnik, Vöröspatak, and Offenbanya; in Spain, formerly worked in Asturias; in Sweden, at Edelfors."—*Dana.*

. . . "In the Russian Urals, at Beresof, and other places on the eastern or Asiatic flank of this range, and the comparatively level portions of Siberia; also, in the Altai Mountains; also, in the Cailas Mountains, in Little Thibet; sparingly in the rivers of Syria, and other parts of Asia Minor; in Ceylon, China, Japan, Formosa, Java, Sumatra, Western Borneo, the Philippines, and New Guinea, Australia, and Queensland."—*Dana.*

. . . "In Africa, at Kordofan, between Darfour and Abyssinia; also south of Sahara, in the Western part of Africa, from the Senegal to Cape Palmas; also, along the coast opposite Madagascar, between the twenty-second and thirty-fifth degrees south latitude; in the Transvaal republic. Other regions are Tasmania, New Zealand, and New Caledonia."—*Dana.*

"In America.—It occurs in Brazil (for many years furnishing the bulk obtained), along the chains of mountains which run nearly parallel with the coast, especially near Villa Rica, and in the province of Minas Geraes; in Venezuela, south of Cuidad Bolivar; in numerous branches of the Orinoco; on the northern coast and the island of Aruba; in New Grenada, at Antioquia, Choco, and Giron; in Chili; sparingly in Peru and Mexico; in the north, British Columbia, Canada, Nova Scotia, New Brunswick, and Lake Superior."—*Dana.*

Article IV.

GOLD AREAS IN THE UNITED STATES.

In the United States.—The distribution of gold in the United States is extensive and the localities are numerous. The remains of an Indian mining village, of very early times, and consisting of thirty-eight low timber houses, were found, buried nine feet below the surface of the ground, in Nacooche Valley, Georgia. The period elapsing after abandonment and rediscovery in the present century is unknown. The Appalachian and Allegheny chain of mountains, in the basement strata of which is the source of the gold, start in the Dominion of Canada, ramifying through Nova Scotia (a gold area), continue traversing the New England States, Pennsylvania, Virginia, the Carolinas, and Georgia, to the Gulf of Mexico.

In Virginia, where gold is most abundant when the iron ore and quartz are combined, it is worked in syenitic and slaty rocks, composed of chlorite, felspar, mica, talc, quartz—in varying proportions. These alternate with veins of quartz which traverse the whole series. The quartz cellular, tinged with red and brown oxides of iron, in which the gold is most plentiful where the decomposition is the greatest—the decomposed ores which overlie the virgin sulphides below the water-line. Southward, the counties of Cabarrus, Lincoln, and Mecklenberg, N. C., Union, Lancaster, and Chesterfield, S. C., and the northern portion of Georgia, mainly comprise the explored gold field. This region formerly produced $1,000,000 annually. To the north gold has been found sparingly in Vermont, New Hampshire, in the beach-sands coast of Maine, in other New England States, and periodical discoveries are now and again announced in New York, New Jersey, and Pennsylvania, whilst several silver

mines have been profitably worked in some of the New England States. To the west gold has been found in the gravel of Illinois and Indiana.

In California gold was discovered along the western slope of the Sierra Nevada, and subsequently found through the whole length of the great north and south valley which holds the river and plains of the Sacramento and San Joaquin. In this range gold has been found from the Tejon Pass, latitude 35° northward, through the Shasta Mountains, Oregon, Washington Territory, and into British Columbia. The drift of gold is followed southward to Arizona and New Mexico and on the eastern slope, in Nevada and Utah.

Between the eastern and extreme western areas we have the eastern slope of the Rocky Mountain regions. The States and territories of Colorado, Montana, Wyoming, and Dakota continue to add new areas or mining districts, some of them, as Leadville and Deadwood, of novel and surpassing wealth.

Article V.

THE GEOLOGICAL OCCURRENCE OF GOLD.

Native Gold.—An alloy of gold and silver with traces of copper, iron, and other metals. (Sp., from 19.25 to 12.66.)

Palladium Gold.—Rhodium Gold. Native amalgam of gold and mercury.

Two Ores:

(1.) Sylvanite or graphic tellurium—telluride of gold and silver.

(2.) Nagyagite—telluride of lead, gold, silver, and copper.

With the exception of the tellurides, native gold is the only important form in nature.

General Occurrence.—In the popular fancy gold finding is accidental, because usually found in alluvial washings. On the contrary, certain geological conditions and a somewhat narrow scope of characteristic rocky matter indicate its probable presence, and in the absence of which it is not found, unless from secondary causes. It is pretty well settled among scientists that investigation starts with its metallic condition*—infinitessimal particles—and the accretion of such atoms, in a quartzose matrix, a portion of the vein-filling of fissures or clefts in the crust of the earth. Whatever may have been the relative location of these clefts or fissures as to the surrounding lay of the country,† the modern surface or outcropping is not that of the primitive condition. Numerous agencies—

*See Note No. 23. †See Note No. 2.

heat, floods, erosion, and denudation—have worn away and distributed vein matter and the country rock to the depth of thousands of feet, in some instances, and in all cases more or less. Hence the finding of gold in alluvium, sand, gravel, conglomerate, and cement,* in the shape of fine particles and water-worn plates and scales, and, occasionally, crystallized specimens.

GEOLOGICAL AGE.—Gold formations and occurrence of gold are marked by distinctive characteristics wherever the metal has been found. The general range is that from the older paleozoic up to the cretaceous, and it is not confined, as supposed by some, to the silurian rocks.

"It is found in the secondary or Mezozoic rocks; it is wrought in rocks of the carboniferous age in Nova Scotia, and in California, veins traversing strata of Jurassic and Triassic age give good results."—*Phillips.*

1. The vein formations—quartz lodes or ledges of California—traverse crystalline slates interbedded with and intersected by porphyritic and serpentine rocks, the whole backed by the central granitic and gneissic rocks of the mountain chain, making on the surface a series of ridges parallel to the main axis of the great chain.—*Davies.*

2. In a vast series of crystalline and metamorphic rocks—green, gray, purple, and blue slates gneiss and gneissic rocks, which over large areas are changed into quartzite of an almost uniform texture of a bright and clean gray color.—*Davies.*

LE CONTE'S THEORY OF VEINS.—"There seems no reason to doubt, then, that in most cases at least, vein stuffs have been deposited from hot alkaline solutions. . . . *Metallic sulphides* are by far the most common form of *ore*, and even when other forms exist, we may in many cases trace them to sulphide as their original form. . . . There is abundant evidence that the

* See Note No. 10.

auriferous quartz veins of California have been deposited from hot solutions. . . . Again, there can be no doubt that the associated metallic sulphides were deposited from the same solutions as the vein stuffs, for they are completely inclosed in the latter. But the gold exists as minute crystals and threads of metal *inclosed in the sulphide of iron*, and must, therefore, have been deposited from the same solution as the iron." . . . "We conclude, therefore, that metalliferous veins have been deposited from hot alkaline waters, circulating through fissures, and that in the case of auriferous veins, the solvent of the gold was sulphate of iron; and the sulphate was deoxidized by organic matter in the same solution, the gold and the iron crystallizing at the same moment—one as metal, the other as sulphide. Gold is sometimes found in pure quartz without the sulphide of iron. In these cases it may have been in solution in alkaline water as silicate of gold, as suggested by Bischof."

THE THEORY OF DANA is somewhat similar and compactly set forth. "The origin of gold veins is little understood. The rocks, as has been stated, are metamorphic slates that have been crystallized by heat, and they are the hydromica, chloritic, and argillaceous, that have been but imperfectly crystallized, rather than the mica, schist, and gneiss, which are well crystallized; and the veins of quartz which contain the gold occupy fissures through the slates and openings among the layers, which must have been made when the metamorphic changes or crystallization took place. It was a period, for each gold region, of long continued heat (occupying, probably, a prolonged age) and also of vast upliftings and disturbances of the beds; for the beds are lifted at various angles, and the veins show where were the fractures of the layers or the separations and gaping of the tortured strata. The heat appears not to have been of the intensity required for the better crystallization of the more perfectly crystalline schists. The quartz veins could not have been filled from below by injection; they must have

been filled either laterally or from above. In all such conditions of upturning and metamorphism the moisture present would have become intensely heated, and hence had great dissolving and decomposing power; it would have taken up silica with alkalies from the rocks (as happens in all geyser regions) along with whatever other mineral substances were capable of solution or removal; and the vapor, thus laden, would have filled all open spaces, there to make depositions of the silica and other ingredients it contained. These mineral ingredients would have been derived either from the rocks adjoining the veins or open spaces, or from depths below through ascending vapors. By one or both of these means the quartz must have received its gold, pyrite, and ores of lead, copper, and other materials—all having been carried into open cavities at the same time with the silica or quartz. The pyrite of the vein is usually auriferous, showing that it was crystallized under the same circumstances that attended the depositing of the gold in strings, crystals, and grains."

A Serious Doubt Suggested.—With reference to these theories, in every other respect well sustained, it may be asked: Since such deposition of vein-stuff was exceedingly slow, requiring indefinite time, how were huge fissures of great depths, stretching for many miles longitudinally, prevented from falling in, caving, closing from the sides,—the prevention of which now, in mines where this vein-stuff has been removed, is a very laborious and expensive work in mining? However this may be answered no theory yet propounded covers satisfactorily so many points.

Theory of Davies.—"Therefore it will be seen that gold occurs in rocks of the same age and under similar conditions all the world over. That all the gold-bearing rocks lie below the carboniferous group. That the general horizon of the most productive rocks lies at what in North Wales is the

junction of the lower with upper Cambrian, the horizon of the Lingula flags and the beds below. That schists or slates of a steatitic, talcose, and chloritic nature, with granite and greenstone rocks of the same age, are the best depositories of gold. That it is finely and sparsely disseminated throughout the whole of the above rocks, but segregated in quartz beds and veins. That in quartz it is most abundant where iron pyrites, titaniferous iron, and other ores of iron prevail."

Sir R. Murchison's Silurian Theory.—"Appealing to the structure of the different countries which at former periods have afforded or still afford any notable amount of gold we find in all a general agreement. Whether referring to recent history, we cast our eyes to the countries watered by the Pactolus of Ovid, to the Phrygia and Thrace of the Greeks, to the Alps and Golden Tagus of the Romans, to the Bohemia of the Middle Ages, to the tracts in Britain which were worked in olden time and have either been long abandoned or are now scarcely at all productive, or to those chains in America and Australia which, previously unsearched, have, in our times, proved so rich, we invariably find the same constants in nature." This was Sir Roderick Murchison's silurian theory, as the true age for gold, and the sole contributor of those "constants." More recent thought and data contradict this, or rather, widens the range, as every other theory has its opponents, whether as to vein-filling, geological age, or the accompanying rock—curiously giving reason for ranking the poet, philosopher, and prophet Job, as an expert in geology, since he was the first to announce: "Surely there is a vein for the silver and a place for the gold where they find it."

Article VI.

AURIFEROUS VEINS, FISSURES, OR LODES.

Fissures.—These undoubtedly were the original rocky sources of the drift metal. The erosion and disintegration of the rocky matter, already spoken of, dislodged the fine particles and caused their intermingling with the drift, shingle, and alluvium in which they are now found. The larger size and diminished alloyage of these particles, however, and the frequent finding of massive lumps, or nuggets,* differing in these respects from the gold as now found in veins, at first, and for a long while, caused doubts of their original source,—as the product of vein decomposition. This doubt is in the main removed by recent speculation as to the cause of the accretion of the drift particles. It is assumed as quite demonstrable that favorably-situated particles of drift gold became the attractive nuclei for a new deposition of gold from auric solution, under the influence of which a new growth and crystallization increased their size. If gold in the vein matrix was precipitated from solutions it is easy to extend the operation of the same law to drift particles, and thus account for increase of size and the usual diminution of alloyage found to be a characteristic of drift gold.

The seven or eight billions of gold actually garnered by man being, then, mainly the product of veins, as originally formed in the crust of the earth, we come to a realization of the magnitude of deposits contained in the many thousands of veins opened and to be opened, some of the former having been profitably wrought for two thousand feet in depth.

*See Note No. 3.

Gold in Veins.—The native gold found in the modern tops or outcropping of veins lies generally in a quartzose gangue, at times associated with iron and copper pyrites, sometimes with arsenical pyrites, blende, and galena. Operative mining has discovered those veins, as a general rule, to be most productive which afford considerable quantities of disseminated sulphides.* Usually, near the surface, or for some distance below the outcropping, as in Colorado, these sulphides have, in nearly all cases, become decomposed, liberating the inclosed granular gold and staining the quartz of a brown or reddish color. Gold, in veins of hard, white quartz, without sulphides, in most instances, is found in flakes and granules of considerable size, visible to the eye. Such veins furnish cabinet specimens and usually fail to be regularly and remuneratively productive. On the other hand, some of the most steadily remunerative veins are of moderate size, and seldom exhibit visible gold free from its almost invariable associate—the sulphide of iron, and, perhaps, copper.

Free Gold Quartz.—Quartz is the most abundant source of vein filling. Granitic decomposition and antemetamorphic conditions of rocky matter supply the needed constituents for this vein matrix, and also the metallic sulphides. Practical working shows in the decomposed zone above the water-line dry and hard quartz which, on breaking, exhibits free gold in cavities, yet bearing the impress of the minerals which once filled them—square spaces, exactly conforming to the surfaces of the cubical pyrites, and in many cases these have been obliterated by subsequent deposition of quartz in fine crystals and the fine gold remains inclosed in quartz freed of sulphide—hence the free gold quartz, if not formed as indicated by Bischof.

Below the water-line, or zone of decomposition, the interspaces remain filled in with sulphides. Broken samples, after acid

* See Note No. 4.

treatment, exhibit the cavities and perhaps the gold, as in decomposed pieces taken from the upper zone. Hence productive veins are rarely found in hard crystalline rocks unless they have undergone decomposition and replacement, such decomposition indicating the former intimate association of the gold with the decomposed and deported sulphide.

DEPTH OF VEINS.*—Enough has been done by the quartz miners in large areas, in this country and elsewhere, to prove that veins may be wrought with profit to great depths below the surface, since the bulk of the evidence points to the simultaneous deposition of the gold with the quartz, and other minerals which fill them indefinitely downward.

Metalliferous veins are clefts, cracks, or fissures, generally extending through the whole series of strata to unknown depths, not necessarily the effect of a violent upheaval. They may be produced more frequently by the shrinkage of the strata than by any other cause. Technically so named, fissure veins have a generally east and west direction, varying most frequently about forty-five degrees on either side. They dip, or incline downwards, at various angles from the horizon—usually more perpendicular in hard rock and sloping in slate. They are characterized by displacements, slips, or faults; contain "horses" (bunches of foreign rock), and often divide into branches. The Cornish are accustomed to call small lodes "veins," and the fissure proper a "lode," since all veins are not fissures, and may be what are termed "gash veins," or "network veins," or irregular deposits, readily exhausted. Beds are flats, irregularly-stratified mineral deposits, often occurring at the place of contact of two dissimilar formations or groups of rocks. They are at times composed of segregated and crystallized masses of ore, and exhaustible usually at shallow depths.

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* See Note No. 5.

These fissures in time become filled with a variety of mineral, largely partaking of the adjoining rocks, and thus arises the classification of the contents, whether of mineral exclusively or of metal and mineral, forming the various kinds of metalliferous lodes. In limestone the fissures are charged with carbonate of lime and fluor spar; in clayey strata of the silurian rocks, with baryta. Lead lodes in limestone abound with calcareous breccia, or cemented masses of fragmentary kindred rocks, and in the carboniferous strata chert, sandstone, and millstone grit are abundant. The harder slaty rocks furnish a large proportion of silica, and so of granite, if decomposable, its silica being redistributed in the vein filling.

METALS IN VEINS.*—The primary condition of the metals and the subsequent distribution of them in lodes, as now found in selected associations, in special formations, and aggregated under conditions having great uniformity in the case of each special metal, encompass an inquiry which has vexed controversial geogonists from very early days to the present time. Assuming an elemental metallic condition and a fluid state. aggregation and dissemination would follow through and after violent disturbance and when cooling commenced. These two conditions would be acted upon very diversely in subsequent changes, whether by heat or action of alkalies or acids, or by both. Displacement, erosion, and recomposition through various agencies must have been frequent. Sedimentary strata being formed from mineral and of metal in suspension, the latter whether in disseminated grains or in solution, metamorphism commenced subsequently upon the material which, in cooling and crystallizing, became fissured, holding at the same time the mineral and metallic matter to refill the voids. These constituents of matrix, vein-stuff, and metal, reaching the clefts by percolation, permeation, or infiltration, then precipitation, crystallization. The power of water and alkaline

* See Notes Nos. 6 and 7.

liquids, especially when energized by heat, to dissolve, take up and carry to the fissures these constituents, is not an open question. Whether they did or did not, and how the metals were disposed in the antemetamorphic strata, are the controversial points, and so they may remain. A hint of the theoretic condition of an interesting inquiry is all that is proposed.

VEIN CHARACTERISTICS.*—A careful reader will find many popular fancies with regard to exhaustion, pinching, impoverishment in depth, and other like queries, answered by a fair conception of this probable formation and theoretic infilling of fissures. It will be observed that no fixed *criteria* can be had on such questions beyond such geological "constants" which are prerequisites to the finding of metalliferous areas. When found and fissure-veins are discovered, holding auriferous deposits, the concomitants of each vein must be studied as disclosed by working. The fissure will be rich or poor in metal and will show the vicissitudes incident to all such operations in nature. Nevertheless, experience has shown certain characteristics to be more or less reliable. True fissure-veins are likely to be persistent in depth, in quantity, and quality of metalliferous deposit. Admixture of sulphides betokens an original presence of the best conditions and largest supply for vein-filling matter, containing metal in solution.† The characteristic disposition of the lode when found is likely to mark its subsequent history. The condition of the walls, the gouge, and longitudinal extent of pay-chutes will afford reliable data for a close estimation of probable value. In fact a lode or vein fairly developed is usually out of the category of hazards, is good, indifferent, or worthless, and can be so adjudged with nearly the same certainty as a field may be pronounced good, indifferent, or worthless, for the raising of any named crop. Nor is the working out of the product subject to any greater hazard, nor

*See Notes Nos. 8 and 9. †See Note No. 4.

as much, when essential conditions of working have been established.

Of vein or lode enumeration there are no statistics. Several thousands have been productively worked in the United States. The recording of one hundred thousand lodes has been asserted of Colorado. Official statement credits eight hundred and eighty square miles in Australia with two thousand five hundred and fifty-one exploited auriferous reefs. The gold-belt area is said to be one thousand miles long. In Russia the Ural gold area is set down by Boglubski at two million square miles. The gold area known in the south was estimated in the early days at one thousand square miles. Professor Raymond estimates the gold area of California alone equal to the area of the State of New York.

Article VII.

GOLD WASHING OR ALLUVIAL GOLD.

Evidently gold was first procured by the gold seekers of ancient days from drift sand and from the beds of rivers.* Away back in the Scripture days (B. C. 1520) Eliphaz said to his friend by way of consolation: "Thou shalt lay up gold as dust, and the gold of Ophir as the stones in the brook;" doubtless meaning gold nuggets, which must, accordingly, have been somewhat common. Pliny (A. D. 50), some fifteen hundred to sixteen hundred years later than this, remarked: "In these parts of the world where we live (Spain, possibly,) gold mines are found, to say nothing of India, where the ants cast it up out of the ground, or that which the Griffins gather in Sythia. The gold is procured with us in three ways. Among the sands

*See Note No. 23.

of some great rivers, as the Tagus in Spain, the Po in Italy, Hebrus in Thrace, Pactolus in Asia, and the Indian Ganges, all of which yield gold. It is also obtained by digging it out of pits sunk for that purpose; or, again, it is obtained from caverns and breaches which occur from the fall of mountains." The reference to "pits," "caverns," and broken ledges may start the inquiry, whether Pliny did not allude to vein mining. In some degree, doubtless, this was his meaning. The arastra, the simplest means of grinding rocks, must have been known to the ancients. The use of quicksilver in amalgamation, although ascribed to Medina (1567), is said to have been practiced by the ancients, who were fully aware of its properties. Stone troughs and large stone bowls have been recovered in the old workings of mines abandoned for ages. Hence it is not unlikely a portion of gold was amalgamated from pounded rock, obtained from caverns and exposed veins, when rich. But nearly the whole mass of gold down to the discovery of the metal in California was won from drift and river bottoms. There was needed the simplest machinery for washing; and much, no doubt, was obtained by pounding the hard lumps with mallets or clubs; then concentrating by pouring the stuff in the wind from dishes or pans, the air blowing to one side the fine and worthless matter; repeating the operations of pounding and winding until the concentrate becomes rich enough to wash in bowls. This is yet practiced in many places, the writer having witnessed it within two years on an island in the Caribbean Sea.

The wealth obtained in this way by rulers and chiefs must have been very great. An Egyptian king is said to have had an annual revenue from mines of $30,000,000. "Carthage," Heeren remarks, "trusted to her gold, and her greatness was founded upon sand and gold dust." Among the largest fortunes possessed by private persons, in ancient days, a great number were amassed from gold and silver mining; and it is not an open question that many of the most high-sounding *causa*

belli of kings, emperors, and potentates of the great past had the coin and bullion of the enemy as the basis of aggression. Cæsar, as Alexander, was a marauder and plunderer of gold. The building up of cities and their being sacked and plundered arose from the same cause, plethora of gold, derived from the extraordinary profits of placer mining, whether by slave labor or otherwise.

This species of mining has been classified: (1) Distribution of placer gold by the present river system, known as "shallow diggings;" (2) Distribution by the ancient river system, called "deep diggings."

Placer Mining.*—Shallow digging commenced in this country at the beginning of the century. The Cabarrus nugget, found in 1799 by a Mr. Reed, in North Carolina, became the initial. This nugget is said to have been the second, one previously found being as large as a smoothing-iron, the value and nature of which was unknown to the finder, who, after keeping it for some years, sold it for a few cents to one wise enough to remain reticent on the subject. The Cabarrus lump weighed thirty-seven pounds troy. About one hundred pounds in nuggets were found before 1830, each over one pound in weight. In 1829 one weighing ten pounds was found. The United States Mint coined native gold in 1825. From 1804 to 1827 the production reached only $110,000, all from North Carolina. Virginia, in 1829, furnished $2500; South Carolina, $3500. In 1830 Georgia deposited in the mint $212,000. The production of placer mines increased to $1,000,000 per year, which continued for some years. The United States mint at Dahlonega, Georgia, coined near $500,000 in 1852. Del Mar rates the United States' native production at $200,000,000 from 1776 to 1848.

Mining from shallow diggings commenced in California in 1848. Very speedily the whole western slope of the Sierra

*See Note No. 10.

Nevada was under prospecting operations. Southwardly to Arizona, New Mexico, and Colorado, and northwardly into Oregon and Washington Territory, even to British Columbia, the golden drift has been followed and washed. On the Pacific coast range, the ancient and present beach for some three hundred miles, contain auriferous sands, whilst soundings far into the ocean, under deep water, prove their distribution over large areas of the sea bottom. All the bullion produced previously to 1852–3 came from these shallow washings. The largest nugget produced by California weighed one hundred and thirty-four pounds seven ounces.* A very beautiful mass, valued at $4000, was found in 1865.

The earliest gold-seekers used the pan, pick, and shovel. Then followed the cradle, fixed upon rockers, with movable hopper and slides. Following this "the Tom"—long toms and broad toms—wooden troughs placed in a gently-sloping position, with riffles across. As larger works were undertaken these were superseded by the sluice—artificial or natural. The former, a series of troughs, often raised on trestle-work, a fixed bottom and a movable one, the latter with holes. The natural sluice, a ditch or channel-way in the ground, at the proper declination, the bottom paved with planks, or with movable cobble-stones, rammed in, leaving corners and spaces for the catching of heavy matter, or to hold quicksilver. The water and dirt, properly fed at the upper end and mingled in their course, allowed the heavier gold particles to fall and be saved on the bottom.

Deep Digging.—Progressing from the earlier, and now seemingly trifling operations, when the dirt was carried to the water, hydraulic mining was introduced, the water being taken to the auriferous dirt or gravel banks in immense quantity and with great force. In 1873–4 there were seven hundred and seventy-five mining ditches in California, aggregating in

* Blake.

length four thousand eight hundred and sixty-three miles, carrying a flowing burthen of three hundred million cubic feet of water daily. Some portion of this water is used for mill-power, but the greater part for hydraulicing purposes. The deep diggings, or old river system, called into activity the highest engineering skill, and now employs a prodigious capital. What is termed the Big Blue Lead has been traced a distance of sixty miles, with a varying depth from the surface to three hundred feet below. Miles of tunnels have been run under hills and mountains to obtain a fall and room for the *debris*—three things being essential to success:—(1) an auriferous deposit of large area; (2) ample supply of water from a high head; (3) space for dumping or for the tailings. With these prerequisites a few cents per the ton of earth will afford a handsome profit, when working on the large scale.

In Nevada county, sixteen millions cubic yards averaged thirty cents per cubic yard. In Placer county, forty-three millions cubic yards averaged less than five cents per cubic yard. In Yuba county, twenty-five millions averaged twenty-six cents per cubic yard. The quantity of earth removed per man varies from fifty to two hundred cubic yards, according to hardness and the facilities. The La Grange Hydraulic Mining Company removed six hundred and eighty-three thousand two hundred and forty-four cubic yards, at a cost of .038 per cubic yard—average yield, .066 per cubic yard. Operations on the most favorable conditions have demonstrated a cost of less than one farthing for the removal of a cubic yard. The larger portion of the gold now won in California is the product of hydraulic deep mining. This system has latterly been introduced into Russia, and for some time has been employed in Australia. Montana contains hundreds of square miles of drift, auriferous sand, some of which is now yielding handsome profits. An amount of gold wholly beyond calculation remains to be developed and secured by means of the powerful appliances now used in "deep digging" enterprises.

Article VIII.

THE WORKING YIELD OF AURIFEROUS ORES.

There is, as a matter of course, a relation between the yield and the value contained in the rock.* The closest mechanical working will leave in the residues a value. Whether that value is less or more constitutes good or ill, profitable or unprofitable, working. Heretofore mechanical means have but rarely been aided by chemical agencies. The stamp mill and continuous amalgamation, while the rock is being comminuted, make up the usual outfit for reduction and extraction. The variance between the yield and the contents of the rock from time to time suggested modifications, additions, and new attachments, and slowly brought about the further aid of chemical agencies, especially when sulphides proved to be the chief cause of diminished yield or profit.

Yield in California.—The *yield or product* obtained under the best present conditions of working auriferous rock, not the *value*, is now the subject of consideration. Consulting Raymond's Reports, the data may be gathered for calculating the average yield of one million tons of quartz, reduced in several years, in twelve counties of California; and again, taking tabulated reports of some forty mines from which nearly five hundred thousand tons were worked under the best conditions, we reach an average of, say, $20 per ton. Could the data be had of many concerns working low-grade ores, from $6 to $15 per ton, this average yield would be very considerably reduced.*

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* See Notes Nos. 11 and 12.

Yield in Colorado.*—The product and ores of Gilpin county may be taken as representative of Colorado in these respects. Here the ores are largely sulphide, demanding a treatment by smelting in aid of the mill. A portion of the rich ores are selected—and in many cases concentrating follows the mill work—adding concentrates to the selected ores, both of which go to the smelter. For an aggregate of rock worked during several years, amounting to eight hundred and thirty-eight thousand tons, an average of four and five-sevenths per cent. of selected ore and concentrates went to smelting works. The average yield by smelting is calculated to be $141.25 per ton. This, rated on the whole number of tons worked, gives an average yield of $5.20 per ton, the product of the smelting ore. The ninety-five per cent. worked by mill yielded $9.30 per ton by average. Total yield, then, $14.50 per ton.

Reports of Australian yield furnish data for calculating the yield of six million three hundred thousand tons, including high and low grade ores, from $6 to $40, omitting, however, the ores worked at a profit, which yielded but two pennyweights ten and a-half grains=$2.50. The average yield is found to have been about $14.00 per ton.

Former reports of yield at the Moro Velho mines, Brazil, put the yield of two million tons at $8.20. In recent years closer work, and perhaps better ore, has raised the average to $15.00 per ton, or thereabouts. These are representative works, doubtless the largest in the world, reducing one hundred thousand tons of rock annually.

Statistics of total quantity mined and worked in the United States are not within reach, if any such exist. California certainly reduces from eight hundred thousand to ten hundred thousand tons annually; Colorado one hundred and fifty thousand tons.

*See Notes Nos. 13 and 14.

Article IX.

THE STAMP-MILL AND ATTACHMENTS.*

The ancients left no remains of a stamp-mill as now constructed. Stone troughs and hollowed rocks, perhaps the arastra also, were used for comminution. Attempts at mining in the solid rocks, in modern times, were made in Russia in 1823. Sixty and odd mines were opened, but work was subsequently abandoned on all of them, mainly for want of proper means of reduction. The property now owned by the St. John del Rey Company, in Brazil, was first secured in 1725 from the original adventurers for $100. Repeated failures and bankruptcies of undertakings followed, until finally rude stamping machines made of wood were erected. After 1830 profitable working commenced. For 1878 the aggregate reached $1,500,000.

The California Stamp-Mill.—The first stamping-mill imported into California, in 1849 or '50, was from England, and of the wooden pattern, the stems shod with iron and falling into pot-shaped mortars. The mill of the present day is, therefore, of California origin and embodies within itself superior merits. The whole structure is of iron, excepting foundation timbers—the side pieces and stays, which may be of wood. The stamps consist of iron stems; above are iron tappits keyed fast, but movable; below stamp-heads fixed, and movable shoes; this in one piece, thus arranged, may weigh from three hundred to one thousand pounds; usually six hundred to six hundred and fifty pounds. A

*See Notes Nos. 14, 15, and 16.

horizontal shaft, armed with cams and revolved by power, is so fitted as to cause each cam to come under each tappit to raise, and let fall by gravity, the above weight of iron. The rise is from a few inches to nine or more, the rapidity, as desired, up to one hundred drops per minute. These stamps work in batteries of five and in an inclosed high mortar of iron; a feeding side and a discharging side, the latter covered with perforated iron or wire screen. On the bottom of thick iron there are five iron dies upon which the stamps fall, or crush the interposing rock. The feeder shovels broken ore into the mortar and gauges the water needed and the addition of mercury. The grinding, pounding, and attrition goes on in the mass, and the comminution of ore and quicksilver is supposed to bring the freed gold in contact with the latter. Amalgamation follows. Copper plates, previously amalgamated, are fastened within the battery at the discharge, and at times on the back below the feed. A large portion of the amalgam is obtained from these inside plates and from the key-holes of the stamp-heads. In front the pulp and water fall upon additional copper plates placed at a gentle decline, additional amalgam adheres to these amalgamated surfaces. From these tables or plates the flow continues either to the discharge at once or is guided through additional means of grinding and amalgamation, or is made to pass over concentrating devices of a variety of styles. The early mode of flow concentration consisted of sheepskin—the wool side up. The blanket superseded the skin and remains as one of the chief methods of stopping and gathering the heavier particles of mineral or amalgam. Many mechanical devices or constructions have been introduced to be placed so as to take the flow of the mill and separate out the more valuable portions which would otherwise find their way to the stream. Some concerns resort to buddles.

The concentrates from any of these methods are usually rich, and are reworked mechanically either in pans, barrels, or other

ways. In later years it has become the practice to submit such concentrates either to smelting or to the Plattner chlorination,—both costly, but close in extracting the metal.

With some modifications in practice the mill system and mill-tail attachments are in use for beneficiating the sulphide ores of Colorado. With this difference, however, that the smelting ores proper are first selected out and the balance, about ninety-five per cent. of the ore treated, is termed milling ore and so treated by the mill. These latter contain disseminated pyrites amounting to an average of little less than twenty per cent. Of this sulphide contents the sulphuret of silver is a valuable constituent, nearly all of which is a total loss. None of it is amalgamated, and ores containing this combination, when afterwards worked for a concentration carefully and closely conducted, lose as high as seventy per cent. in the water. Very little, therefore, can be saved in the mill-tail attachments. Beside this other sulphides also become infinitessimally fine and flow off with the constantly-running stream which is heavily charged with ore particles and therefore dense.

Article X.

PRESENT TREATMENT AND METHODS OF WORKING SULPHIDES.

With the exception of Colorado, auriferous quartz is wholly treated in the stamp-mill as it is brought from the mine. The freer this rock is of sulphides the closer is the extraction by battery amalgamation and such additional aids as suit the ores or please the operator. When the sulphides exist beyond two or three per cent. the difficulties commence and loss increases. Pyrites, pounded or ground fine in the presence of mercury, affect the latter mostly chemically, "sickening or fouling," as it is termed, forming a mercurial sulphide film which coats the finely divided particles of this fluid metal. In addition there is sulphate water present, and perhaps other acid agencies, which, during the attrition, pounding, and trituration, tend to divide and alter the healthy condition of the quicksilver. The result is that the silvering of the gold particles is made difficult. This is increased, most operators believe, by a rusty coating on the gold particles also, which tends to annul the active affinity of the two metals, one for the other. The union of the two under such conditions in extremely minute atoms, if it occurs, is likely to make a source of loss, such particles being less disposed to unite on the amalgamated plates, inside or outside of the battery, and may be borne off in the water. Particles of quicksilver so fouled refuse to adhere together or run into each other and also pass off in the water, so that a loss of both metals follows, while the particles of gold, still inclosed in or adhering to sulphide, go off with the pulp. These, briefly, are some of the troubles found in amalgamating sulphide ores.*

*See Note No. 22.

The processes other than or in aid of the stamp-mill consist of three metallurgical steps: (1) concentration; (2) oxidation; (3) extraction.

First.—CONCENTRATION.—The class of concentrators used in the continuous operations of the mill need not again be referred to, further than to say, many are meritorious and do all that could be expected under the conditions. The invention and use of concentrators, using water as the medium, is of European origin, especially German or Prussian. The poor class of ores found and worked in those States compelled a resort to means of reducing the bulk of worthless matrix, of which all the useful metal ores, unless iron, consists, whether or not valuable for silver or gold. The constructions for this purpose almost exhaust the whole range of invention. Notwithstanding this, however, inventors in this country have entered upon the same course, and many water devices now claim public attention. Other inventors have pursued an entirely different line, taking air to be the best medium. Machinery for dry-ore concentration at one time attracted very great attention, some establishments adopting the entire system. Several years have passed without adding to their number. By either of these systems it is proposed to separate all the valuable from the worthless portions of the ores.

Second.—OXIDATION.—American invention has been prolific in this field since the early trouble with sulphides in Colorado. The object sought is the dead-roast or complete driving off the sulphur or other volatile matter, intending a perfect oxidation of the base metals, metalicizing the silver, or chloridizing it, if salt is used, and leaving the gold as nature deposited it, a metallic crystalline dust. The old form of furnace for doing this is known as the reverberatory, and, improved in some features, it stands at the head for special work. Its limit is two-fold—expensive in plant per ton and

costly in operation, fuel, and manual labor. Improvements, in the shape of revolving hearths and mechanical stirring, follow the reverberatory principle, lessening the cost of manual labor, but for some reason they have not superseded the old form. Next followed revolving cylinders, working charges automatically. The Bruckner has occupied an important position in chloridizing silver ores, but has not been used in simple oxidation of auriferous pyrites to any noticeable extent, if at all. This works in charges; another, the White-Howell, works continuously. The chief departure in furnaces was that of the Stetefeldt, invented for chloridizing silver ores whilst falling down, in fine stuff, through a heated shaft, the salt mixed with the ore mass. Working well in chloridizing, they have not been made serviceable for oxidizing pyrites. Other devices have been patented and great claims are preferred in favor of their adoption. All really need some method of concentration precedent to the most economical working.

Third.—METHODS OF EXTRACTION.—The sulphides have been changed to oxides. Theoretically, after fine grinding, they are now fitted for extraction by amalgamation. At the outset of the troubles encountered in Colorado the two steps, oxidation and amalgamation, were proposed as the process for extraction. Several large works were constructed to carry out the designs of the inventors, but misadventure followed, involving serious losses of money and confidence. In smaller ways and with various modifications this system has failed to work with practical success, excepting to a very limited extent. The difficulty, doubtless, is caused by imperfect oxidation, or the presence of sulphates in the roast.

EXTRACTION BY SMELTING.—The failure of the amalgamation system for treating sulphide ores opened the way for smelting, or rather made it a necessity. The foundations of the Boston and Colorado Smelting Works were laid when

repeated disasters had caused an abandonment of all processes of oxidation extraction, throwing the whole field open to the stamp-mill for the milling ores, and to smelting for the selected ores and concentrates. Since then these two methods of extraction have produced the bulk of bullion yielded by Colorado ores. Many smelting concerns are now in operation in the Western mines, even to the Pacific coast. Ores containing copper, silver, and gold are usually smelted in the same furnace, whilst argentiferous galena and gold are reduced in another. The production of matte holding the precious metals with copper, and of bars of lead holding the two former, demands considerable outlay for plant, and the working cost is also large.* Besides this, the mine-owners are required to employ means of concentration or be satisfied with a hand selection and such a concentration as may be had at the tail-race of the mill. The remedy has proved to be only partial, as will be seen when discussing the loss or waste in the mill-treatment of sulphides.

By Chlorination.—About the time that smelting was undertaken for extraction in Colorado the Plattner process of chlorination was being introduced in California. A Mr. Deetken made the first demonstrations in San Francisco, then practically, in Grass Valley. Since then works of chlorination have been erected in many localities, and at some individual mines a single furnace is kept in use for the concentrates.

This mode of extraction has been practiced with very few modifications until recently, as it was when first adapted for working the auriferous arsenical wastes at Reichenstein by the inventor. Under the management of an experienced operator by far the larger bulk of auriferous sulphide ores can be worked with great closeness of result and with a high degree of uniformity. For such ores alone, or when worked simply for

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* See Note No. 20.

gold, the process is more economical than that of smelting, and preferable in many respects, and the extraction as close, if not fuller. Many reasons, however, have operated to confine extraction by chlorine to the working of concentrates only, at mills or in locations where mill concentrates are easily procured. A large chlorination establishment for working in the large way has not been attempted, and perhaps could not be under the old conditions, which are somewhat as follows:—

THE PLATTNER PROCESS OF CHLORINATION.—(1) The auriferous concentrates having been perfectly oxidized, are moistened with water, and put lightly into a wooden vat or cistern having a perforated false bottom, upon which a filter is made, for which there are numerous ways. When filled, a close-fitting cover is placed; and (2) chlorine gas, produced by decomposing salt and peroxide of manganese with sulphuric acid is introduced between the false and true bottoms, (the gas being first washed by passing through water, to arrest hydrochloric acid), and made to permeate upward through the ore mass. After the expiration of from fifteen to thirty hours the gas is found to appear abundantly on the surface and is shut off. (3) The cover being removed, pure water is added to fill the cistern even with the top surface of the ore. The fine particles of gold, under the action of chlorine, have changed from metal to a soluble terchloride, and in this condition it is drawn off, or leached out with the water, fresh being added until a test shows no trace of gold. (4) Sulphate of iron, a prepared solution, being on hand, is the usual precipitant, which, being carefully added to the solution, throws down the gold as a black or brownish precipitate; this is then to be gathered, washed, and melted, or run into ingots of nearly pure gold.

Such is a general outline of the Plattner process, omitting essential details. Of course the capacity of a vat is limited, much water used, and the working of each charge consumes from twenty to forty hours. Hence, in case of large opera-

tions, many tons daily, the number of vats needed and the amount of water to be handled, would demand an immense space, and a prodigiously cumbersome establishment. These considerations, in addition to the dependence upon an expensive roast, have tended to restrict the use of an agent for the extraction of gold in all other respects unrivaled.

Article XI.

THE LOSS OF GOLD BY STAMP-MILL.

First Waste of Metal.—The first waste of metal in the common methods of reducing and amalgamating in the stamp-mill is one improperly disregarded in practice. The loss by float gold, viz., that atomized through abrasion mechanically, in addition to those native infinitessimally small particles, both of which may remain suspended in the muddy water, and fail in part to be brought in contact with the heavier, because so much larger, particles of mercury. It is a well understood practice to judge of the carat fineness of gold by the color of the streak made when scoring a piece of test stone with the lump or coin under examination. This streak, compared with another made from gold of known carat fineness, decides the relative value. The same abrasion occurs in the grinding friction going on with great force within the battery or other pulp-making machine. Of course no estimate can be formed as to the extent of this abrasion, but it can not be otherwise than considerable. With regard to the levity of such color particles one need only remember that gold in the metallic state can be suspended in liquid for months in particles of such extreme tenuity as to be

recognized only by the color.* Practical operators do not estimate what they can have no visible evidence of, and since such suspended particles pass away into the stream they are ordinarily carried beyond the means of obtaining samples for assay.

Mr. Paul, of California, and others, have investigated this subject with much pains and under circumstances which entitle their conclusions to a merited consideration. Many assays were made of settlings from water caught at a distance from the mills. The list of results shows a sufficient presence of both gold and silver to make the loss in this way a matter of serious concern. Mr. Paul estimates the loss to be equal to twenty per cent. of the value of that saved by amalgamation. Where the ores contain the brittle sulphide of silver the loss in this way may readily reach twenty per cent. of the value of the gold which is saved by the mercury.

SECOND WASTE OF METAL.—The second waste of metal is one of some importance, but easily tested by assay of the tailings, if they are fully stopped—that arising from particles of gold remaining wholly or partly enveloped in the matrix not sufficiently comminuted. No estimate of this loss can be assured unless the quartz crushed contained no sulphides, which, of themselves, if present, will in whole or in part contain the loss when a sample of the tailings is assayed. The most careful working of any quartz whatever by the stamp-mill shows a waste of ten per cent., rated on the amount contained. And this has been the case when every possible effort had been used to stop all the sulphides and the heavier pulp by blankets and other means usually employed for such purpose. Extraordinary care is taken in this respect at the St. John El Rey mines, in Brazil, operated by an English company. Here a loss in the tailings is estimated at ten per cent., after a thorough system of saving machines had been passed,—doubtless a loss to be attributed to ineffectual comminution, or coarse

*See Notes Nos. 17, 18, and 19.

particles. In Australia, during eighteen months' milling of eighty-five thousand two hundred and fifty-one tons and daily assay of the tailings, the yield being only $6.52 per ton, the average loss was found to be $1.56 per ton, or twenty-four per cent., rated on the amount saved.

Mr. Deetken, of Grass Valley, Cal. (Raymond's Report, 1874) for determining the loss of gold by mill process, tabulates a series of assays made of the tailings of one of the best mills in the State, which show the loss to have been forty per cent. of the yield, of which the float loss was nearly fourteen per cent. Investigations of this kind are rarely permitted, hence such data are scarce.

THIRD WASTE OF METAL.—The greatest cause of loss, however, is that arising from the presence of sulphides in the quartz. It is now a recognized fact that the bulk of auriferous quartz is that accompanied with sulphides, disseminated through the rock also in massive bands or in bunches.* The solution theory of vein-filling requires the concurrent presence of the sulphide forming constituents as essential factors. The association of gold and sulphides has accordingly been found almost universally, and as a rule the wealth, persistence in depth, and the uniformity of auriferous veins mainly depend upon the presence or absence of sulphides and whether abundant or sparse.† Purely free-gold quartz is rare, and if found rich it is in narrow ribbon veins, or if poor, in massive rock, containing it in particles invisible to the unassisted eye. The importance of this cause of trouble in quartz-gold extraction has compelled recognition in spite of every effort employed by operators and vendors of mines to conceal or claim its presence only in harmless quantity. A successful method of closely and cheaply extracting the gold from auriferous pyrites would speedily change the number of free-gold quartz mines offered for sale by transform-

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*See Note No. 6. †See Note No. 4.

ing most of them into veins of "strongly sulphide quartz." The want of such method leads to a misnomer, in order to conceal or lessen the cause of difficulty—sulphides.

The loss of metal arising from the reduction of quartz containing auriferous pyrites, of course, depends upon the metal contents of the rock. Pyrites differ in gold value, as must be the case, since the auric solution may be heavily or lightly charged with metal at the time of its precipitation and simultaneous crystallization with the sulphide. A well-washed parcel of sulphides will show a very rich result in gold on the one side, and on the other a small value, both parts being pure sulphides. The concentrations in California, gathered after the battery, assay from $80 up to $600 per ton.

LOSS IN CALIFORNIA.—Professor Blake (Report on Precious Metals, Paris Universal Exposition, 1867), states:—"Nearly all of the auriferous veins of California are composed of white or bluish quartz, with, in general, not over two per cent. of sulphurets. These sulphurets are chiefly ordinary iron pyrites, with, occasionally, a little galena and blende." Others rate the sulphide contents of these ores at three per cent. The writer is of the opinion that an average of six per cent. will not cover the sulphide contents of the California ores milled annually. The reasons for this opinion are obvious: (1) The California mills *save* more than two per cent. on the average; (2) the mill-tail methods are, necessarily, merely expedients, designed to remedy a loss, as far as may be done without trouble or additional cost. These can not and do not save one-half of the finely-pulverized sulphides.

It is universally recognized as an established fact that not even the best machines for saving, and the most elaborate care in regulating the feed and discharge, will effect the collection of even forty per cent. of metalliferous ores when finely *comminuted in a stamp-mill*, which is of all methods to be avoided

in careful ore-dressing. When used for such work and crushing coarsely, Rittenger states the product to be—

Sand		32 per cent.
Flour	32 per cent.	
Dust	36 " "	
		68 " "

And the average loss in concentrating argentiferous ores to be—

Coarse sands,	average loss of metal	40 per cent.
Middle fine,	" " "	35 " "
Slimes,	" " "	60 to 70 " "

The most serious loss of metal is because of the flour and dust—slimes—allowing a trifling recovery of the fine particles. The sixty-eight per cent. is the average result when the stamping is done as a *step* in separation, when fine stuff is to be avoided so far as is possible; whereas, this *step* for amalgamation is *fine work*, and the subsequent separation an incident. These contrivances, therefore, and the self-acting or automatic "take-it-as-it-comes" methods used at the mill-tail do not get forty per cent. of the sulphides contained in the ore milled. The actual average saving is nearly three per cent. and the loss is beyond four per cent. of the sulphides contained.

The above large value of the concentrates per ton is mainly due to this waste. The poorer sulphides with gold are swept off with the water. That which is most loaded with gold is what remains, and worth not less than an average of $150 per ton. A loss by sulphides, therefore, of $6.00 per ton of ore milled in the State may be safely estimated. With these elements the following may be taken as the representative loss by milling in the State of California:—

Loss by float gold and in the sand of the tailing (low estimate) fifteen per cent	$3 00 per ton.
Loss by waste of auriferous sulphides in tailings	6 00 " "
Total waste by mill process	$9 00 per ton.

Which, added to the yield, gives the ore a value of $29 per ton for the best and most carefully worked mines in California.

In the absence of data for estimating the annual output it is assumed that five hundred thousand tons would cover the product of these best mines of the State. In 1867 there were four hundred and eleven mills, with five thousand stamps, and also four hundred and nineteen arastras. The above gross would only be an average of less than one thousand tons to a mill yearly, or an amount not equal to the capacities of the arastras alone, if regularly worked. It is very probable, therefore, that fully one million of tons are actually treated in the State yearly, five hundred thousand of which yield an average of $10 per ton, thus fixing the average yield of California ores at from $14 to $15 per ton. Great numbers of small works are not reported at all. Some foreign companies publish no statements, and quite a number, working low-grade ores, refuse to make such information public.

Loss in Colorado.—The purpose of this writing can not be so well served by a new statement as by republishing facts, figures, and conclusions reached eight years ago by the writer and others, and given to the public at that time.

The subject is an important one and will bear a somewhat elaborate setting forth.

(See Appendix for calculations in detail.)

Value of Colorado Ores Estimated from Calculations.

Smelting Ore.

202 assays—official assayer—average	....	$142 75
102 lots sampled, "	....	124 48
104 " " private assayer	....	147 26

Value of smelting ore, average $138.16 per ton.

Milling Ore.

Reichenecker's average, \$41.82 and \$30.00	\$35 91
Average of four hundred and twenty-eight assays from two hundred and eighty-two mines, official and private assays	40 14
41 samples from forty-one mines	33 95
25 tons from six mines, in lots for concentration	27 60
860 tons from the workings of one mine	27 07
10,000 tons from working one mine	33 17
General average per ton of mill ore	\$32 97

Calculated value of mill ore, with per ton value of smelting, pro rated at \$5 per ton added, viz:—

Mill ore		\$32 97
Smelting ore		5 00
Calculated value as mined		\$37 97
*Working yield by mill	\$9 30	
" " " smelting	5 20	
		14 50
Loss of gold and silver		\$23 47

Probable Loss Annually.

Colorado mills about one hundred and fifty thousand tons of rock yearly.

150,000 tons, at \$38.00 per ton		\$5,700,000
Yield by mill	\$9 30	
" smelting	5 20	
	\$14 50=	2,175,000
Loss annually may reach		\$3,525,000
Loss in California, calculated on a production of only five hundred thousand tons		4,500,000
Probable loss annually may reach		\$8,025,000

It is to be understood that silver exists in two conditions in these ores: (1) Metallic alloyage with gold; (2) independently,

* Actual average yield of ores milled and ores smelted, calculated from Fossett's Tables—(seven years' work).

as a sulphuret of silver. The bullion obtained has its proportion of metallic silver, the alloyage. The gold lost carries its silver alloyage. Then, as the sulphuret of silver can not be amalgamated in the battery or on the plates it goes wholly into the tailings. This mineral being brittle and flaky, when suspended fine in water, floats readily. Hence, much of it is not stopped, if the tailings are saved, and when these are buddled a very large part of that once stopped goes off from the buddle; if the mill-tail concentrators are used the quantity saved is insignificant.

Estimates in 1871.

Value of mill ore by assays		$32 97 per ton.
Value saved by mill	$10 88	
Value saved by reworking tailings	5 16	
Loss by mill flow and reworking	16 93	
		32 97 "

The Source of Loss.

Value sent to tailings	$22 09	
Value reclaimed	5 16	
Total loss may be		$16 93 per ton.
First by mill flow	$7 89	
Second by buddling	9 04	
		16 93 "
The loss of gold is	$ 5 89	
The loss of silver is	11 04	
		16 93 "

By working poorer ores since 1872, because of the cheapening of supplies and labor, the seemingly high estimate of $37.97 per ton can be reconciled with the low product obtained now by the mill and furnace, viz.: $14.50 per ton; instead of obtaining a yield of $10.88 + $5.16 by mill and reworking, and $5.20 by smelting = $21.24, which should be the yield of ores worth $37.97 per ton, and yet allow for the serious loss of gold and silver.

Possible loss by mill treatment, $22.09.

Yield $16.04 + loss by mill, 16.93	$32 97
Yield by smelting	5 00
Calculated value as mined	$37 97

Opinions of Writers on "Gold-Milling" in Colorado.

(Quoted from London *Quarterly Journal of Science*, January, 1873, article on the "Gold Mines and Mills of Colorado," by James Douglas, of Quebec, expert and metallurgist, inventor of the Hunt-Douglas Copper Process.)

"*Methods of Treatment.*

"* * The gold caught on the plates is, under the most favorable circumstances, only forty per cent. of the assay value of the ore. The quantity of silver saved is inconsiderable. The gold from the blankets and in the buddle concentrates does not amount to more than five per cent., so that, when treating the most tractable of these sulphurets, battery amalgamation and tailing concentration do not secure more than forty-five per cent. of the gold, and therefore involve a loss of fifty-five per cent. of the gold and all of the silver, copper, and lead. As already stated, it is second-class ore that is milled, or that from which has been separated by hand the solid sulphurets, and from which has been thrown away stuff too poor for treatment.

"The benefit of tailing concentration is so insignificant from the simple fact that it is so carelessly and rapidly conducted" (as in California,) "that only the largest and heaviest particles can settle in the voluminous and swift stream of water used. Most of the tailings carry more than one ounce of gold to the ton, about two per cent. of copper, and fifteen per cent. of iron pyrites and blende galena. The concentrate will consist of almost pure iron pyrites, very little, if any, more copper than the crude tailings contained, and seldom as much as two ounces of gold."

Prof. Raymond's Report, 1870, *page* 364:—

"It is impossible to state accurately what percentage of gold is lost in milling, as few assays are made either of the crude ore or of the tailings; but that a very large amount is lost can not be doubted, and this loss probably varies from thirty to

seventy per cent., according to the nature of the ore. None of the silver is saved except a small quantity, which being obtained in the gold, merely diminishes the value of the latter metal."

Fossett's Colorado, page 292:—

"It is estimated that more gold has been wasted in milling and has been washed down the creeks and gulches than has been saved."

Albert Reichenecker (*see Appendix, page* 80 *et seq*).

"The proportion of gold saved on the plates and tables varies, in a well-constructed mill, between thirty and fifty per cent. of the whole amount of gold in the quartz, and may average forty per cent."

Article XII.

THE PRESENT CONDITION OF INDUSTRIAL GOLD MINING.

It will be apparent from these brief outlines that gold mining as an industrial pursuit encompasses interests of immense importance when the whole field of enterprise is brought into view. The sources of the metal are practically beyond the measure of any method of calculation. The great extent of mineral area, the cosmical profusion displayed in nature with reference to all deposits of useful metals and substances, the expansive surface exploited and depths attained by practical working in widely-varying and separated localities, all tend to demonstrate the number and magnitude of workable veins of gold. In connection with this, it is also apparent that great progress has been made in structural and dynamical geology, whereby the constitution of the earth and the physical and

chemical changes hitherto effective in disposing of its abundant elements may be interpreted with almost unfailing accuracy. Then in the department of applied science, whether in relation to mechanical technology or that having to do with analysis or synthesis, we seem to be arriving at a stage of development which renders possible and easy now what hitherto seemed to be impracticable, if not seemingly forbidden. Thus former hazards, incident to the finding and estimation of values hidden in the earth, are so lessened that it might be said they are removed; those relating to the mode of mining them and placing them on the surface stand now as one to ten in former days, and such hazards as once seemed invincible, or almost prohibitive of profit in handling what had been mined, no longer give cause for serious worryment or hesitation.

INEFFICIENCY OF THE STAMP-MILL.—But notwithstanding this very satisfactory view of progress made, it is also apparent that the wise conservatism of experience adheres too tenaciously to methods and practices which were born within the narrow boundaries of necessity, and have grown strong through aids devised to supply defects and reconcile inconsistent purposes. It is seen that the stamp-mill, admirable and efficient for certain duties, has been harnessed to work for impossible results. The work of comminution done and the amalgamation finished, uncontrollable incidents furnish the figures of a loss entirely too important to be disregarded—an annual waste of many millions—made under the present best condition of mill reduction, supplemented by every aid and adjunct offered by concurrent invention. A shortcoming so serious as that which has been demonstrated implies some defect of a fundamental character. It is fair to presume, and no captious criticism is intended, that necessity has built a superstructure, made additions, and shaped new attachments to cover and utilize a mechanism otherwise to be abandoned as entirely inadequate and unsuitable. That this

inference is not a forced one, without reason, or made with facile proneness to censure, it is needed only to study the incongruities brought into a forced co-operation, for the purpose of remedying evils owing their existence to agencies and activities which should not have been set in motion. If float gold runs into an uncontrollable loss; if pounding sulphides and commingled mercury form mercurial sulphides; if acid sulphate fouls mercury and causes waste of both metals; if comminution leaves metal still entangled in matrix, and each of these untoward happenings calls for a new diagnosis and some eclectic remedy, which at best is only palliative—perhaps, it would be wiser not to give scope to such agencies and activities. This is the kind of work done by the stamp-mill, driven to the performance of an uncongenial duty, and thus becoming the mother of evils through illegitimate labors. This is the present condition of quartz-mining industry and its surroundings, provocative of amazing waste, initiating needless hazards, inducing speculative and gaming ventures, and frightening timid capital from encountering uncertainties needlessly occasioned or inconsiderately increased. No industry other than a sound one could suffer this and flourish. If for this condition there is a remedy, it must be suggested through the cause of the difficulties and be fundamental.

Both logic and business forecast unite in advising the treatment of auriferous sulphide quartz by a process devised and fitted for the economical and close handling of auriferous sulphides.

Article XIII.

THE MEARS IMPROVED METHOD OF EXTRACTING THE PRECIOUS METALS FROM AURIFEROUS SULPHIDE ORES BY CHLORINATION.

Three important agents control the extraction of the precious metals—heat, mercury, and chlorine gas—ranking as proficients heretofore interchangably in many respects. Hereafter the latter will take first rank as the universal agent of economical extraction. Since the initial experiments with chlorine in California no serious impediment to its successful application has been encountered in the beneficiation of almost all auriferous mineralized combinations. Its application in practice has, however, been narrowed and limited to small workings, to rich concentrates, and under special circumstances. Operators, experts, and inventors yielded a willing assent to a seemingly autocratic power within these limits, but beyond which they believed its economical sway could not be carried. Hence the chlorine method remained unaltered, unless in mechanical detail of handling and the lessening of some chemical minutiæ, at first deemed essential by the inventor. The enlargement of its powers by discipline, the curbing and mastering of its activities by compulsion, were not, or seemed never to have been contemplated.

The Mears Invention.

The discovery of Dr. J. Howell Mears, of Philadelphia, has the simplicity of Franklin's "electric key,"—the locking-up of hitherto uncontrolled power, subjecting it to order, method, and measure, the harnessing of it to disciplined effort for perfecting in one hour a duty which, at will, required from twenty

to forty hours. The merit of the discovery rests in this condensed and increased force of disciplined work, vastly accelerating perfect results. The scope of labor thus opened embraces the larger portion of the auriferous ores, which may now be handled cheaply and conveniently without waste in the residues.

Since the issue of the Mears patent continued tests, followed by practical working on the large scale of tons, have settled the mode of practice, perfected the detail, and by the unfailing regularity of satisfactory results obtained, assurance is given of a new departure in extracting the precious metals from auriferous mineralized ores.

THE PLATTNER PROCESS.—The merit of Plattner's discovery rested in the practical application of chlorine gas for the extraction of gold from oxidized ores, and is based on the fact that this gas vigorously attacks and transforms metallic gold into a soluble terchloride without materially affecting the base metallic oxides. The old method may be briefly described as follows:—

1. The auriferous ores, if mineralized with sulphur, arsenic, &c., are "dead-sweet roasted," cooled, moistened, and loosely sieved into a cistern or vat having a double bottom, the upper perforated and covered with a stratum of filtering material.

2. Chlorine gas—evolved in a leaden generator by sulphuric acid, salt, and peroxide of manganese, or omitting the first two, and substituting hydro-chloric acid—is caused, after passing through water, to enter between the upper and lower bottoms of the vat through leaden pipes. The gas permeates upward, making its presence known by its odor, when the top of the vat is securely placed and luted.

3. Pure water, after from fifteen to thirty hours, is added, sufficient to cover the ore mass, the top having been removed. The terchloride of gold being soluble in water, is dissolved; the solution is withdrawn or leached out into proper receptacles until a test shows no trace of gold left in the residues.

4. Sulphate of iron, common copperas in solution, is the usual precipitant, throwing down the gold in a brown or blackish loose powder, which may then be gathered and melted into bars.

Such eminent metallurgists as Large, Richter, Georgi Duclos, the original inventor, and others, by extended and exhaustive experiment, clearly settled the conditions essential to a successful carrying out of the Plattner theory in practical operations.

These conditions are:—

First.—The gold contained must be in the metallic state. In case sulphides or arsenides are present, sulphur and arsenic must be expelled by the agency of heat, roasting,—transforming the metals into oxides. The combinations broken up, the gold is freed in its native metallic condition.

Second.—The expulsion of the volatile matters must be perfect, leaving no sulphides or soluble sulphates of the metals, otherwise transformations of the first into chlorides and a waste of the chlorine would follow. From these chlorides sulphuretted hydrogen may be evolved, which precipitates the dissolved gold in the mass. From the sulphides also the chloride of sulphur results and reactions produce hydrochloric and sulphuric acids, which, in turn, attack the metallic oxides. The presence of sulphates precipitates the dissolved gold; the soluble metallic salts also contaminate the final precipitate.

Third.—The chlorine must be freed from hydrochloric acid gas by passing through water, otherwise, being present, the metallic oxides are attacked and dissolved; and, should undecomposed sulphides remain, sulphuretted hydrogen would be generated and act on the dissolved gold, precipitating it in the roast-mass.

Plattner's successful application of chlorine was made in 1851 at Reichenstein, Silesia, on arsenide waste, containing gold in small amount. The importance of his success was speedily followed by numerous modifications. Calvert projected the treatment of "nascent chlorine." Kiss another method. Patera practiced with a solution of salt saturated with chlorine, chloridizing and dissolving the metals in the same operation. Rözner roasted with salt, and used a hot solution of salt for dissolving, &c. It is not known that any of these methods are now notably practiced.

The usual precipitant employed to throw down the gold in metallic condition, already mentioned, is the sulphate of iron. Numerous other reagents or substances may also be used—such as sub. chloride of arsenic, sulphurous acid, sulphuretted hydrogen, phosphorus; organic substances—coal, saw-dust, leather, &c.; and the metals—iron, copper, zinc, mercury.

THE MEARS-PLATTNER PROCESS.—Briefly stated, the Mears improvement derives form and force from compressed chlorine confined in a revolving cylinder containing the auriferous roast-mass.

The advantages consist in expedited action, an important contraction of the operating area and appliances, therefore great economy in material, in handling, and in outlay for plant; to which is added a close, if not a closer extraction of metal than by the old free-range process according to Plattner.

THE MEARS SYSTEM.

1. *Generator.*

CHLORINE is generated in the usual manner by sulphuric acid, peroxide of manganese, and common salt, or if preferable, by hydrochloric acid and manganese. The generator is of the ordinary construction and of a size proportioned to the work proposed.

2. *Gasometer.*

A gas-holder, or gasometer of metal, properly protected and of moderate size, is used, as like tanks for illuminating gas, and for a like purpose, as a magazine to hold a constant supply.

3. *Gas-Pump and Reservoir.*

Connection pipes of lead intermediately connecting a specially-devised force-pump with the gasometer and a strong reservoir, into which the force-pump compresses chlorine to the required degree of pressure, thereby also obviating the necessity for a large gasometer.

4. *Chlorinator.*

Connecting pipes, adjustable to a cylinder of iron lined with lead, the cylinder revolving on trunions centered on the heads and resting in boxes firmly seated on the iron frame support, one trunion being hollow, to which the connecting pipe is adjusted. Central on the periphery of the cylinder a man-hole

fitted with an adjustable cover. All assailable parts protected with sheet-lead and the parts firmly bolted together and capable to resist a pressure much greater than the working maximum, and indicated by an attached pressure gauge.

5. *Filter.*

Filtering vessels with prepared bottoms, transportable on wheels, into which the chlorinated charge is dumped from the cylinder, water added, and from which the liquid or solution containing auric chloride is filtered or leached out until a test shows no trace of gold.

6. *Precipitating Vat.*

Vessels or receivers for the solution and for precipitating according to the method practiced.

With this plant the operation is carried out as follows :—

1. *Charging and Chlorinating.*

A charge, consisting of two thousand pounds dead-roast, is put into the cylinder, and to this one hundred and twenty-five gallons of water added. The thorough mixing is then effected by revolving the cylinder. After having exhausted the atmosphere, to prevent adulteration of the chlorine, the charge of chlorine from the pressure reservoir is admitted until the gauge indicates the required density. The chlorine is then shut off and the cylinder kept revolving from thirty to sixty minutes.

2. *Discharging.*

The chlorine having by this time thoroughly dissolved the gold in the dead-roast, the excess of gas under pressure is allowed to pass off either into the gasometer for reuse, or into a newly-charged cylinder to chloridize another ton of dead-roast. The gas remaining in the water, held by absorption, is expelled or drawn off by means of a vacuum produced by adjusting the connections with the pump. The chlorination being finished and surplus gas discharged, the whole contents are run into leaching vats.

3. *Filtering.*

The leaching is finished when the liquid no longer shows a trace of auric solution in the sample tested.

4. *Precipitating.*

This solution is then ready for the precipitating agent. If the sulphate of iron, it is added until a test sample shows no discoloration on adding a few drops of the sulphate. If charcoal, then this auric solution is run through barrels properly filled with carbon, two or more to be used for absolute security that the whole of the gold will be deposited.

5. *Reducing to Bullion.*

In the first case the precipitate is to be washed, some sulphuric acid being used to clear it of contaminating matters, and then it may be smelted into an ingot with borax, &c. Or, in case carbon is used, the rich gold concentrate is to be dried and incinerated, the ashes washed out, and the gold smelted as in the previous case.

Working by the Chlorinator and Chloride of Lime.

Omitting the generator, gasometor, and gas-pump, good results will be obtained by employing Chloride of Lime, adding the proper proportion of sulphuric acid to evolve the gas immediately in the charge of dead-roast. In such case the charge of ore is first put into the chlorinator, then the chloride of lime, to which the acid is added, and the cover being placed, the chlorinator is set in motion. The evolution of the gas is at once made apparent by the pressure-gauge; at first going to the maximum of pressure, and then lowering as the gas does its work. This method is employed for tests in the laboratory, for working trials, and has been practically used in the large way, working tons of ore daily. The results have been entirely satisfactory.

Systematic Operations.

These simple, progressive, and systematic operations serve to extract and put in the form of bullion the entire auric contents of the dead-roast, seldom leaving beyond a trace—not over fifty cents per ton—if the operation has been conducted with the care that the systematic conduct of the process demands and makes easy. In an establishment working several tons of dead-roast continuously, thus exhausting the powers of the chlorine needed for keeping up the pressure, only, or mainly that absorbed by the water is wasted. The cost of a quantity absolutely required for dissolving the gold bears about the relation of twenty-five cents to $240 in gold bullion.

PROCESS FOR SILVER AND COPPER.

As at present advised, the Mears Chlorination Company commend no special means for claiming the silver and copper which will be chloridized in the process when employed for the gold. The former metals constitute an irregular quantity or value, and there are many ways for their recovery well known and practiced. A selection from these methods is left to the option of those electing to use the process for gold.

Very shortly the Mears Company will be prepared to furnish special information on this subject.

COMPETITIVE COST ESTIMATES OF THE OLD AND THE IMPROVED SYSTEMS OF CHLORINATION.

The primary consideration in the practice of chlorination is a perfect roasting of the mineralized ores. For this purpose the furnace formerly preferred was the old reverberatory or a modified construction, in terrace or double hearths. Mechanical or revolving hearths and other devices have been proposed, and, to some extent, have been used with more or less satisfaction. Furnace estimates were ordinarily placed at $1000 per ton of daily capacity. This may now be reduced to less than half that cost.

Cost per ton by Old System.

The careful estimates of expenses per ton, published in Raymond's Reports, 1874, pages 344–45, and made by Professor Deetken, the originator of chlorine works in California, aggre-

gate, for roasting, \$4.87, and for other work, including materials, \$6.23=\$11.10 per ton. Of this amount he states the cost of chlorination proper to be \$2.21 per ton of dead-roast. Under these prices, only to be reduced by the fall in prices of material, labor, and, perhaps, in furnace manipulation and fuel, chlorination by the Plattner process has continued to fill the narrow groove of working rich concentrates.

Cost per ton by the Mears System.

The Mears Company at present use a revolving hearth; but with regard to this precedent step of roasting the selection of a furnace is still an open question, and must necessarily be left to the option of those who may elect to use the process. Any furnace well performing the work will answer the purpose, due economy being a matter of mutual interest to all concerned.

The cost for chemicals is not subject to change, whether to be used in the Plattner or the Mears process; and the same may be said with regard to items of other material and wages. Assuming a reduction of twenty per cent. since 1874 in material and labor, the above estimate of \$6.23 would stand now, in round numbers, say \$5.00 per ton for cost of labor and chlorination proper.

The sources of saving in the Mears process are—

1. The expedition and lessening of labor exceeds one-half, or reduction to	\$1 81
2. The conservation of chlorine by reuse exceeds three-fourths, or reduction to	44
Thus reducing the above cost from \$5 per ton to a total of	\$2 25

based on California prices; or chlorination proper from \$2.21 (less twenty per cent.) to forty-four cents. Practical working in North Carolina, where labor is cheap, shows the above total cost to be \$1.91 per ton, with no reuse of gas. This cost is reduced to about one dollar by reuse of chlorine.

Important Considerations.

It is said of Colorado that one hundred thousand locations of mines have been made and recorded by name and ownership. Asssume this to be the aggregate number for the whole mineral area of the United States, in all of the fifteen States and Territories claiming auriferous belts and districts. The proportion of veins in the one hundred thousand which are free quartz is, according to experience, comparatively small. The characteristic auriferous quartz is sulphide, the exception, free metal ores. Many entire districts possess sulphide ores almost exclusively, and the bulk of them of low grade, which may be averaged at twelve pennyweights to the ton, or $12 ore. Such mines are often bold and strong, carrying vein rock easily mined. Treated, as they have been, by the stamp mill, if worked at all (and it can not be claimed that these ores have anywhere been treated by any other process with satisfactory results), the industrial result, at the best, may be stated as follows:—Mining, $1.00; milling $2.00; loss in treatment, forty per cent., $4.80=$7.80 per ton; yield, $7.20=profit $4.20 per ton.

Supposing such ores to be submitted to a treatment by the Mears process, as now practiced at the Yadkin Gold Mine and Reduction Works, North Carolina, and at the same cost as published (1879) viz., $4.16 per ton, deducting 91 cents saved by re-use of chlorine, $3.25—to which add, mining, $1.00, =$4.25—product $11.50; profit, $7.25 per ton. A difference of $3.05 for the owner; but the far more important industrial result is achieved, viz., $4.30 saved, instead of wasting $4.80, in every ton worked.

Saving Waste in California.

In California, calculations from such data as can be secured show about five hundred thousand tons of high grade quartz mined and milled yearly,—quartz-mining in that State, as elsewhere, except in Colorado, being practically limited to mines

having but a small proportion of sulphide ores. The average yield is calculated to be $20.00 from ore worth $29 per ton, loss $9.00;—cost of mining $5.00, milling $2.00—profit to owner, $13.00. Industrial loss, $4,500,000 annually.

Assuming this output to be worked by the Mears process, with no larger outlay for plant, the following would be the approximate result to the owners and to the industry of the nation (the figures for roasting and chlorination are outside of what will be the true costs in the near future):—Mining, $5.00; roasting, $2.50; process, $2.25; loss, $0.50=$10.25 per ton; profit, $18.75, or a net gain of $2,375,000 to owners, by adding only $2.75 to present cost of treatment for the ton. The industrial result to commerce would be the conversion of the above industrial loss into additional bullion, or national wealth, of $4,250,000 annually.

Saving Waste in Colorado.

Assuming for Colorado a total output of one hundred and fifty thousand tons annually, the following calculation is warranted:—

These ores are sulphides, estimated to average twenty per cent. in iron, copper, zinc, silver, and lead sulphurets; rarely without a notable amount of the silver sulphide with the iron and copper pyrites. In order to work these ores a separation is made which practically classifies ninety-five per cent. as milling ores and five per cent. smelting. The cost of mining averages less than in California, say, $3.50 per ton; milling the same, $2.00 per ton. Smelting is always costly. This cost to the owner is not less than $40.00 per ton on the seven thousand five hundred tons, or for the one hundred and fifty thousand tons, $2.00 per ton—$3.50+2+2=$7.50, total cost per ton. The total yield by mill and by smelting is, say, $14.50 per ton,—*the average yield for the past seven years;* and $14.50—$7.50=$7.00, profit per ton of ore mined.

The loss on these ores, ascertained by careful estimates of losses by mill treatment, in the float loss of both gold and silver, and in the loss by sulphides, especially the silver sulphide, may be calculated at $15.00 per ton. There is, therefore, less than fifty per cent. saved even with the expensive aid of smelting, doubling the per-ton mill-cost of treatment.

Whereas, if these ores were treated by the Mears process, at the cost of $4.75, mining $3.50=$8.25 per ton, the product would approximate $29.50 in the place of $14.50 and the owners would derive an additional annual profit of $2,250,000.

Total Saving in two States.

In other words, by changing the methods of treatment in the present mining operations of these States, at an average increased outlay of $2.20 per ton, the total footing up in increased yearly profits for owners would be $4,625,000.

The estimates of loss or waste are the results of careful approximations, worked out from reliable data, and are not overstated. The amount of ore supposed to be worked may be more or less without harm to the purpose involved; there is no question of the abundance of ores worth the value named. As to the costs of the chlorination process and its close working, existing data sustain the stated figures, and the future will speedily demonstrate them to be under rather than overestimated.

These calculations relate to the present mining conditions and output of ores in the two States mentioned. A large majority of the mines known to be rich in sulphide ores are as yet unworked. Mining as a national industry is now for the first time attracting general attention among the commercial and financial men of the eastern cities with views of legitimate enterprise. Their experience is vastly enlarged in this direction, and a wider scope of mining information is within reach

than at any former period. In consequence of this, within the next few years the amount of capital to be invested and the output of ores will probably be tenfold greater than in the past. The importance, therefore, of considering every means of saving closely, and working with the greatest economy, can not be overstated, either in the individual or industrial sense.

The system and apparatus described in the forgegoing pages represent the present plan of operation, which is in no way exclusive as to method, manipulation, or appliances. These are and will be subject to change according to preference, localities, and incidents of experience impossible to foresee. The operative utilization of chlorine under pressure by any preferred method of manipulation is the essence of the Mears Chlorination System.

APPENDIX.

Article I.

Calculations by the Author. (Published in the London Mining Journal, 1872.—Revised.)

Gilpin County.—In this county we are in the apparent centre of a belt of gold and silver bearing veins, crossing the hills, or traversing their façades, as do the stripes on the back and sides of a zebra. The width here may be from five to eight miles, running north and south into other formations. Indeed, properly speaking, there is no way of sharply defining the direction or extent of this or other great mineral belts. In a general geological sense, its eastern boundary is that of the gneissic and granitic rocks of the Rocky Mountain range. The same may be said of the western boundary beyond the range. Between these are many "belts." The formation in which all these lodes occur is, with rare exceptions, granitic and gneissic, here and there porphyritic and hornblendic dykes and patches —a formation favorable to the existence of *fissure veins*, promising the production of mineral indefinitely downwards. The gangue is most frequently quartz, felspar, slaty and porphyritic material, assuming different appearances when differently mixed with these interjected matters. This quartz-rock crops out on the hillsides in white or colored streaks, bunches, and ledges, appearing and disappearing, called by prospectors "the blossom rock," overlying the vein below. When gone down upon, auriferous iron and copper pyrites, zinc-blende, argentiferous galena, and the sulphuret of silver are found; more than one always, and frequently all of them, in intimate admixture.

"Upon this rock" orators and writers are wont to aver such a dynasty, nation, or enterprise struck and went to ruin. Not figuratively, but actually, "upon this rock" the early fortunes of Colorado were most grievously injured and well nigh ruined. Early discoveries were made of blossom

rock, decomposed during countless ages, which decomposition penetrated the vein to various depths. In this matter the gold was free. The production was large by the well-known stamp-mill. Mine owners and sharp speculators went east, with abundant proofs of rich and profitable enterprises. Several millions were expended in the purchase and transportation of machinery, in the erection of works, and in the reckless prodigalities of agents, as though success had been assured. It was quite otherwise. This free gold, decomposed vein matter, was soon exhausted, and the virgin vein rock reached—solid iron and copper pyrites, or interspersed throughout the vein rock—quartz, porphyry, syenite, and gneissic intermixtures. Now there was no decomposition to free the gold. Productive mines suddenly changed to unproductive, though no lacking of ore. Nearly all the companies failed outright or became discouraged. A few halted long enough to incur debts in experimenting on processes, the invention mostly of some sharp, enthusiastic, but ill-informed adventurers in the field of metallurgy. None of these devices were successful, though costing millions in the aggregate, and, unfortunately for the country, giving a bad reputation to the ores, as being "intractable," "refractory," "rebellious."

Here was a dilemma of a most serious character, for which there seemed no relief, nor was there until 1868, when smelting-works were put in operation. Hitherto all the ore raised from the mine, however rich in solid iron and copper pyrites, was sent to the mill. Now what could be hand-selected out had a market at the smelting-works. Thus originated a selection of ore into first-class, or smelting ore, and second-class, or mill ore. The remedy is but partial, systematizing the working loss, whilst demonstrating only a way of treating the ores. The evil of the system consists in the encouragement given to the milling system for the second class ores, which, in fact, contain, interspersed, from fifteen to fifty per cent. of first-class ore connected with the gangue. Hence, the mill only succeeds in extracting a percentage of the gold, losing *all* of the sulphuret of silver and all of the copper yet contained in these sulphurets. The mills erected by the companies being idle, were then rented for the reduction of this second-class ore. The mines unused by companies were leased by enterprising miners, and thus two classes of men were soon educated to continue a business slightly profitable to themselves, but very injurious to the reputation of the mines. In this way, however, mining affairs have jogged along since 1868, the profits increasing somewhat by increase of skill, better machinery, and a more thorough system of working.

From the mines of Gilpin county alone nearly five hundred tons of ore are produced daily, or a total of one hundred and fifty thousand tons annually. Between four hundred and five hundred lodes have been assayed and mapped, all within a circle of three miles in diameter. Fully one thousand lodes have been recorded, upon which more or less work

has been performed. From fifteen to twenty miles of reputable lodes are known to exist within this circle, upon which there are not less than eight miles of shafts, the deepest eight hundred feet. There are not less than twenty miles of drifting on these veins, following the ore deposits in the crevices. The territorial and private assayers have tested thousands of samples from these leads. An average of several hundreds of these tests, samples of mill ore taken in course of daily operation, show this species of ore to run largely over thirty dollars per ton in gold and silver. The average of first-class ore reaches over one hundred and thirty dollars per ton in gold and silver and about twenty dollars in copper, of which no record is made by the assayer. There are eighty-three stamp-mills in the county, one hundred and thirty-five engines in place, four thousand three hundred and sixty-seven horse-power, and one thousand five hundred and ninty-seven stamps, of which there are over eight hundred in use, requiring one thousand seven hundred and three horse-power. There are thirty-nine engines used at the shafts of mines for raising ore from the veins and keeping them free of water.

The pioneer miners and prospectors who started the first mills and arastras, did everything under the pressure of "haste to make a fortune," which would not brook the keeping of accounts or records indicating the value of the ore. When the eastern companies failed they had been in operation too briefly to establish anything of the kind. Since then, nearly all the milling has been done by custom-work, much of it in leased mills for lessees of mines. It was not to the interest of operators to keep or publish a statement of this nature. Hence, up to the present moment, there is no very extended means of establishing the average value of the ores of Gilpin county from working quantities raised from a number of mines continuously. Perhaps I have given more labor to this question than anyone else, and have at hand a sufficient amount of detail to warrant a statement which can be regarded as approximately correct.

Estimate of Smelting Ore.

(*Territorial Assayer's Book.*)

District.	No. of Assays.	Gold.	Silver.
Gregory	106	$143 93	$24 58 per ton.
Nevada	64	92 20	29 54 " "
Illinois Central	12	119 63	35 53 " "
Russell	20	82 88	42 13 " "

Average value of first-class or smelting ore by two hundred and two assays, $142.75.

Assays.						
34	lots from Gregory district average per ton					$169 30
32	"	Nevada	"	"	"	127 92
19	"	Russel	"	"	"	112 18
9	"	Illinois C.	"	"	"	126 96
8	"	Central	"	"	"	86 05

102 lots of ore, samplings of thousands of tons, averaged..............$124 48

No estimate for copper.

From a private assayer's books, one hundred and four lots averaged $147.26. Samples from same districts as above.

Estimate of Mill Ore.

(Territorial Assayer's Books.)

District.	No. of Assays.	Gold.	Silver.
Gregory	120	$25 12	$9 03 per ton.
Nevada	136	26 55	12 67 " "
Illinois Central	39	26 08	19 06 " "
Russel	69	18 13	22 12 " "
Central City	34	22 69	19 58 " "
Eureka	20	27 78	15 16 " "

Average value of mill ore by four hundred and eighteen assays, $40.66 per ton.

(Private Assayer's Books.)

277 lots from same districts averaged.......... .... $33 86
151 lots from private assayer's books averaged............................ 46 42

Average of 428 samples, $40.14 per ton mill ore.

41 samples from forty-one mines, by agents and millmen, averaged per ton..$33 95

These mill-ore assays were made of samples taken from the same two hundred and eighty-two mines at every variety of depth and for every kind of purpose, the most of them occurring in active working, for testing the value of particular ores as reached, inclusive of every sample assayed, some of them worthless as ores. The assays were made during two years, by official and private assayers.

During the summer of 1870, twenty-five tons were taken from six mines, in various lots, for the purpose of testing a concentrating machine. The ore was mill ore of the poorest class, the first-class having been closely selected out. The average by assay was $27.60 per ton.

An operator, more particular than ordinary, weighed a lot of ore as fed to his mill until eight hundred and fifty tons had been treated. Samples were taken for an average of value. The result was $27.07 per ton. The mill saved a trifle less than forty per cent. and the operator lost fifty cents per ton by the mill—a very close verification of Mr. Reichenecker's statement, quoted hereafter. From one mine during two years about ten thousand tons of ore were taken, the first-class selected out and the other milled.

The yield of mill was, per ton	$13 17
The value of tailings in pile (estimated as original ore)	15 00
Estimated loss by flow of mill per ton of ore	5 00
Value of original ore per ton	$33 17

In this instance $13.17 is about forty per cent.; but the operator lost money, the first-class ore being pledged for the use of the mine. His profits went off at the tail of the mill, not less that fifteen per cent., irrecoverably, in the flow of the water—perhaps leaving forty-five per cent. yet in the pile of tailings, which were stopped.

Float Gold, or Loss in the Flow.

Where any effort is made to save and rework the tailings means are taken to check the flow outside of the mill so as to allow the heavy part of the pulp to sink, afterwards to be shoveled into the general pile. In the water which passes on to the main stream there is carried in suspension a very important percentage of valuable mineral; this I have termed loss in the flow. Perhaps it would be interesting to give some examples of this loss:—

		Gold.	Silver.
1869.			
Aug. 21.	Sample of tailings taken out from creek distant from mills	$39 21	$8 58
1870.			
Jan. 12.	Samples taken in same way	33 08	8 84
July 7.	" " "	33 07	10 40
" 7.	" " "	31 01	3 74
	Slimes from box so placed that the finest slimes would have time to precipitate—sample	12 40	2 47

Valuable tailings can be gathered many miles below all the mills. The silver sulphide to a great extent is borne along with the water still further, being too light to fall whilst there is a current.

VALUE OF COLORADO MILL TAILINGS.

LOSS IN TAILINGS.—In order that no exaggeration shall be imputed, it may also be stated that eighty-four assays of common tailings, made by the best assayers of the county in the regular course of business during two years, for actual tests, represent the value of many thousands of tons in piles, either on sale or for buddling. These tailings represent not less than sixty per cent. of the original ore. The average of these eighty-four assays being $23.15 in gold and silver, we have then the value of $13.89 per ton of the original ore in the tailings. Then, for the loss in the flow. Kustel says twelve per cent. of gold is lost in careful concentration, and at times very much more. Rittinger states the loss of sulphide of silver at thirty-five to forty-five per cent. when the best precautions are used. The flow of the mill must then lose ten per cent. of the gold and from forty to sixty per cent. of the silver sulphide.

Calculation.

In pile, as above, per ton of original ore		$13 89
Loss in the flow—gold and silver in alloy	3 89	
*Loss in the flow—sulphide of silver	6 00	
		9 89
Escaped from the battery and tables		$23 78

Now, the buddle saves of this $13.89 only about fifty per cent. of the value, according to tests by experts and the general experience in the county.

*We have then for loss by buddling	$6 94
Loss in the flow	9 89
Per-ton waste from the mill	$16 83

There is reason to believe that the loss is even very much more serious Not one-half of the tailings are buddled, very many in consequence of inaccessibility to sufficient water, some from carelessness, and generally from a general looseness in this regard. Buddlers are a class of themselves—some of them give trouble, some cheat; hence millmen, at times, prefer not to be bothered in attempting to save a product out of which they are likely to be defrauded in the end. It is more than probable that fifty per cent. is not

*See page 81.

saved from the ores raised in Gilpin county jointly by the mills and the smelting works. Had this been the case in California and Australia vein-mining for gold in those celebrated districts would have been abandoned long since. That Colorado can or should survive under such circumstances is of itself an incontestible proof of the great wealth of her gold mines. Correct and reliable information on this subject is so desirable that I feel it worth while to sustain the most important of my conclusions by quoting the labors of others leading to like conclusions, but by very different modes of calculation.*

The Relation of Silver to Gold.

This relation was unnoticed until attention was directed to its importance by the writer. As an alloy silver is never absent, but until these ores were handled mines producing gold ores were not known to hold the sulphides of silver in appreciable quantities. Such ores, until recently, were not recognized as existing in the quartz of California. In the Gilpin county auriferous veins the sulphide of silver is an important element of value, as is also copper. It is, perhaps, sufficiently curious to remark that this sulphide of silver accompanies the mineral when distributed throughout the gangue (in mill ore) to a greater extent than it exists in the solid pyrites (smelting ore) from the same vein, as will be seen from the following figures:—

	Gold.	Silver.
428 assays of mill-ore, made during two years—samples from two hundred and eighty-two lodes................	$22 56	$17 51
(Here $100 in gold carry $77.65 in silver.)		
216 assays of first-class (smelting) ore......................	97 56	33 43
(Here $100 in gold carry $34.26 in silver.)		
78 assays of ores, selected from the poorest mill ore..	61 15	43 94
(Here $100 in gold carry $70.84 in silver.)		

By taking the average of these seven hundred and twelve assays, representative of all the ores raised during two years, we have the relation of $57.58 in silver to every $100 in gold. The average alloy of gold and silver, where gold is found native, throughout the world is about $21 in silver to $100 in gold. The alloy of bullion produced by the mills of Gilpin county is about $20 in silver to every $100 in gold.† As the mills get only the native alloyage, all other silver in the ore escapes amalgamation and is lost if not caught with the tailings. By the average of silver in bullion that loss would be $37.58 gone off for every $100 of gold contents of the ore. But since in many cases the tailings are stopped, piled up, and

* See page 82. † See Note No. 21.

afterwards buddled (concentrated), another element must be taken into consideration.

	Gold.	Silver.
220 assays of tailings (samples taken during two years from several piles, representing very many thousands of tons of original ore) show	$34 92	$8 88

(Here $100 gold carry $25.43 silver.)

Now, if there had been no silver sulphide the gold alloyage in the tailings should show the same relation in silver as in the original ore, which was $77.65 in mill ore, or $57.58 averaged, to the $100 in gold. Hence an irreclaimable loss of silver in the flow on the average of $32.15 to every $100 of gold not saved on the plates.

This loss represents the loss of silver (sulphuret) at the mill flow, the sulphuret being exceedingly friable and easily carried off in the water as slum. But the loss of silver does not stop here. These tailings have now to be buddled (concentrated), whereby another loss of the sulphide which has been stopped is brought about.

In one hundred and thirty-two assays of concentrated tailings (representing the result of buddling very many thousand tons of mill tailings) the relation of silver was found to be $8.58 to $49.42 in gold. Here $100 in gold carry only $17.51 in silver, a loss of silver in buddling from $25.43 to $17.51.

Loss of Gold.

The next loss of gold occurs when the pile of tailings comes to be buddled. This loss will generally reach 40 per cent., perhaps over 60 per cent., of the gold and silver in the tailings. Tests have established this, and it is well known that a pile of tailings never produces a yield anything near the figure expected. Calculations involving a deal of figuring will develop results somewhat like the following, calculated from the data given.

Value in Gold and Silver.

Mill ore contains gold	$18 96	
" " alloyed silver	8 79	
" " sulphide "	10 22	
Estimated value of mill ore		$32 97 per ton.

Gold yield per Ton.

In gold bullion, per ton of ore saved, by mill	$9 07 per ton.	
In gold saved, by buddle	4 00 "	
Yield of gold		$13 07 per ton.

Silver yield per Ton.

Silver saved in alloyage with gold	$2 61	
Sulphide of silver saved by buddle	36	
Yield of silver per ton		$2 97

Gold loss per Ton.

Of the gold there has been lost in the flow from mill	$1 89	
" " " " from buddle	4 00	
Gold loss per ton		$5 89

Silver loss per Ton.

Silver lost in alloyage with gold	$1 18	
" lost as a sulphide from the buddle	3 86	
" lost as a sulphide in the flow from the mill	6 00	
Loss of silver per ton		11 04
Original value of the ore		$32 97

Gold saving short of seventy per cent..............................*Gold loss 30%*

Silver saving short of twenty-two per cent..............................*Silver loss 78%*

Total saving gold and silver forty-six per cent..............................*Total loss 54%*

A loss on the value of the ore of fifty-four per cent. after the expenditure of manipulating cost more than sufficient to have covered a close saving of whole contents. A result equal to this can be assured only by the best conducted works on the stamp-mill and buddle system of working.

ARTICLE II.

EXPERT VALUATION OF COLORADO ORES.

Value of Mill Ore.

Albert Reichenecker*, a graduate of the German schools and practice, after giving the subject a searching analysis, states that the ores must be worth $27.75 per ton to pay expenses in the mills, and hence more than that if a profit is made. He says:—

"The proportion of gold saved on the plates and tables varies in a well-constructed mill between thirty and fifty per cent. of the whole amount of gold in the quartz, and may average forty per cent.

Extraction from mine	$4 60		
Interest on plant	40		
Cost of management	40		
Transportation (by team)	1 00		
Cost of quartz at mill		$6 40	
Crushing and amalgamation		4 70	
Working cost per ton			$11 10

This sum represents the lowest yield which allows a mine to be worked when producing ore worth by assay $27.75 per ton." *Sixty per cent. lost by milling.*

Mr. Reichenecker classifies and values the ore as follows:—

Value of Selected Ore, First Class.

4.5 ozs. gold, at $20.67 per oz	$93 00	
18.1 ozs. silver, at $1.30 per oz	23 50	
9 per cent. copper, $2.00 per cent	18 00	
		$134 50

Value of Mill Ore, First Class.

1.4 oz. gold, at $20.67 per oz	$28 94	
5.6 ozs. silver, at $1.30 per oz	7 28	
2.8 per cent. copper, $2.00 per cent	5 60	
		$41 82

*Aufbereitung der geschwefelten Golderze in dem Rocky Mountains im Colorado Territorium der Vereinigten Staaten (Prag., 1871,) von Albert Reichenecker.

Value of Mill Ore, Second Class.

1 oz. gold, at $20.67 per oz.	$20 67	
4.1 ozs. silver, at $1.30 per oz.	5 33	
2 per cent. copper, $2.00 per cent.	4 00	
		$30 00

SUMMARY.

"The economical results of the whole mining and reduction may now be presented, according to the foregoing discussion, as follows, calculated upon the basis of fifty tons of ore:—

For veins of the first class.

1. *Selected Ore.*

Sale of five tons, at $60.00	$300 00
Cost of mining and hauling	30 00
Profit	$270 00

2. *Mill Rock.*

Stamp-mill (steam-power)—			
Yield of plates, forty per cent. of $29.40 for forty-five tons		$529 20	
Mining and hauling, at $6.00 per ton	$270 00		
Crushing and amalgamation, at $3.84 per ton	172 90	442 90	
Profit			86 30
Pans and dolly tub—			
Yield four per cent. of $29.40 for forty-five tons		$52 92	
Expenses, at fourteen cents per ton		6 30	
Profit			46 62
Concentration of tailings—			
Sale of 2.25 tons, at $16.94		$38 12	
Cost of concentration, at $4.00 per ton	$9 00		
Cost of hauling, at thirty-six cents per ton	81	9 81	
Profit			28 31
Total gross profits on fifty tons rock			$431 23
Deduct for management, taxes, &c.			63 00
Net profit per ton, at $7.36			$368 23

For veins of the second class.

1. *Selected Ore.* (none).

2. *Mill Rock.*

Stamp-mill (steam-power)—			
Yield of the plates, forty per cent. of $21.00 for fifty tons		$420 00	
Mining and hauling, at $6 per ton	$300 00		
Crushing and amalgamation, at $3.80 per ton	190 10	490 10	
Loss			$70 10
Yield four per cent. of $21.00 for fifty tons		$42 00	
Expenses, at fourteen cents per ton of mill rock		7 00	
Profit			35 00
Concentration of tailings:			
Sale of 2.5 tons, at $8.78		$21 95	
Cost of concentration and hauling, at $4.36		10 90	
Profit			11 05
Gross loss on fifty tons rock		$24 05	
Add for administration, taxes, &c		62 50	
Giving a total loss on fifty tons mill rock, at $1.73 per ton			86 55

Article III.

RESULTS OF TREATMENT.

(Quoted as published in 1872, in a review of Reichenecker's book.)

"Gold occurs in the ores of this region almost universally, not disseminated in the gangue, or, at least, only so to a very small extent, but contained in the ore proper, both in iron pyrites and chiefly in the copper ores, while the zinc-blende and galena contain only silver. Auriferous iron pyrites are usually fine grained, loose in texture, and frequently imbedded in or mixed with pulverulent silica, while the gangue proper is a mixture of quartz and (greenish) felspar, or even consists of hornstone. The iron pyrites never contain silver in considerable quantity aside from that which is alloyed with the gold. The auriferous copper pyrites are very seldom fine grained like the auriferous iron pyrites. It is occasionally finely disseminated in hornstone, but usually presents crystalline aggregates with sub-conchoidal fracture, always mixed with aggregates or crystals (usually cubes) of iron pyrites. The crystalline pyrites are traversed in all directions by quartz threads, or mixed with more or less fine granular silica. The copper pyrites always carry silver as well as gold. Next to copper pyrites occur most frequently variegated copper ores, containing considerable gold and silver. With reference to their contents of gold, the veins of this district may be divided into two classes, the total rock hoisted from the first class having an average assay value of $36 per ton of two thousand pounds in gold, containing twenty per cent. silver,* and that of the second class not exceeding $21 (in gold). The veins of the first class comprise scarcely one in a hundred of those hitherto developed.

In mines of the first class the rock hoisted (which has a specific gravity of about three) is sorted, as has been remarked, generally at the time of sending it to grass, and the fragments of richer ore are separated. The weight of the selected ore is four to twenty-five per cent. (average ten per cent.)

* Mr. R. did not have sufficient general data for estimating the average contents in silver, hence places it low. He gives one dollar more, however, in gold to the second class ore than I did in my calculations to the average ores of the district, including his first as well as his second class.—B.

of the total mill rock, *i. e.*, for nine hundred hundredweights sent to mill one hundred hundredweights are reserved as rich ore, and has a market value of $30 to $70 (average, say $60,) for its contents in gold, silver, and copper. The proportion of silver to gold is highly variable; it ranges from one to ten times as much by weight. There may be, on the average, four times as much silver as gold. The proportion of copper is also variable; it bears, however, generally, an approximate relation to that of gold and silver, and may be estimated to average, in the total rock from mines of the first class, three to four per cent. Under these conditions the above average selling price of selected ore ($60 per ton) represents an assay value of—

4.5 ounces gold (per ton)		$93 00
18 ounces silver	"	23 40
9 per cent. copper	"	18 00
Total		$134 40*

"The only smelting establishment purchasing these ores in Colorado pays at the works sixty-three per cent. of the full value of the silver and copper, while the price paid for the gold is considerably less, though it rises with the quantity of gold in the ore. For the above proportion of $93 gold per ton only about thirty five per cent. of its assay value is paid; this gives for the gold $32.80; for the silver $15.20, and for the copper $12, or in all $60, being forty-four to forty-five per cent. of the full value. The mill rock of the first class remaining after the selected ore is removed then contains an average of about one and three-quarters ounces of gold .800 fine (twenty per cent. silver), worth $29.40 per ton. The total contents in gold, silver, and copper average about as follows per ton:—

1.4 ounces gold	$28 94
5.6 ounces silver	7 28
2.8 per cent. copper	5 60
Total	$41 82†

* Two hundred and sixteen assays of this class, heretofore stated, $97.36 gold, $33.43 silver. These two hundred and sixteen assays were made of samples taken for sale of the ore and represent the bulk of first-class ore smelted during two years. Adding for the copper, as above, $148.99 would represent the average value of first-class or smelting ore, according to the tables of assay.—B.

† Four hundred and twenty-eight assays of mill ore, heretofore stated, during two years, $22.56 gold, $17.51 silver—nearly $6 less of gold and $10 more of silver.—B.

"The specific gravity of this mill rock is about 2.9. The specific gravity of the rock from veins of the second class is usually in the neighborhood of 2.8. There is here no selection of the best pieces—the whole is sent to mill. The copper contents seldom exceed two per cent. The whole valuable contents of these veins are, therefore, estimated, at maximum, per ton:—

"1 oz. gold	$20 67
4.1 ozs. silver	5 33
2 per cent. copper	4 00
Total	$30 00* "

"The average assay value of concentrated tailings may be set down as follows: From mill rock of the first class, per ton—

"2 ozs. gold	$41 34
6.5 ozs. silver	8 45
1.9 per cent. copper	3 80
Total	$53 59† "

"From mill rock of the second class, per ton:—

"1.40 oz. gold	$28 94
3.50 ozs. silver	4 55
.5 per cent. copper	70
Total	$34 19 "

"The smelting-works pay for tailings of these grades, respectively, about twenty-one and two-thirds and eighteen and one-half per cent. of the assayed gold value and sixty-five per cent. of the assayed silver and copper value; or for first-class tailings—gold $8.96, silver $5.50, copper $2.48—total, $16.94 per ton; and for second-class tailings—gold $5.36, silver $2.96, copper 46 cents—total, $8.78 per ton.

* In the calculations heretofore stated for both of the classes above I gave $20 gold and $15 silver as the average—less gold, more silver. Perhaps my silver average is large, but in four hundred and twenty-eight assays $100 gold carried $77.65 silver.

† My statement was one hundred and thirty-two assays, $49.42 gold, $8.58 silver, or $8 more of gold—a difference of only thirteen cents in silver, this being the average for all mill-ore tailings when concentrated.—B.

Article IV.

Present Condition of Gold Milling in Colorado.

Since 1871-72, when the foregoing studies and calculations were made, it is said much closer work is done by the mills. This is true only in one sense. The figures of yield do not show closer work, since the yield per ton is not so large as formerly, and no very large increase has been made in the amount of ore sent to the smelter. Hence the total per-ton yield is not greater now than it was eight years back, if indeed it is not less. The progress made in this direction consists in the more general attention paid to the saving and reworking the tailings, and yet more considerably in the present ability to work rock formerly thrown aside as too poor. This latter arises from the cheapening of labor and materials whereby poorer rock can now stand the waste and be worked, whereas formerly only the richer rock would yield a profit beyond the waste.

There is no change—no important change—in working the sulphides more successfully by the stamp-mill process, and the calculations previously given may be considered as exhibiting the present condition of gold milling in Gilpin county.

A Review of the Calculations.

First.—Smelting Ore.—The assays of two hundred and two sample lots averaged $142.75. The *working yield* during the succeeding eight years is $141. 25. In order, however, to avoid the appearance of relying upon one series of assays others were given to make an aggregate for an average to which no exceptions could be taken. In this way the result of $138.16 per ton was reached, when actually the assay turns out to be nearer to the working yield.

Mr. Reichenecker valued the smelting ore at $134.50. It will be seen, however, that he made three classes of ore, one smelting and two milling—the first milling, a rich ore, $41.82. So much then for the smelting ore.

Second.—Milling Ore.—Here, also, unwilling to stand on the assays, four hundred and twenty-three of them—average $40.14 per ton—all the data procurable were aggregated for an unquestionable standard of value. In this way the result of $32.97 per ton was reached. The proof is indubi-

table that the ores sent to mill in 1871–72 must have been worth this amount or more to yield a profit beyond working cost and the waste. If ores of less value can be worked now and a profit be earned it is because of cheaper labor and material and more care in reducing tailings in which the waste occurs.

Third.—Value of Ores as Mined.—By prorating the yield of smelting ores, the relation being five to ninety-five in the hundred. The prorated value fixed by calculation was $5.00 per ton. The working yield for the seven following years is seen to have averaged $5.20 per ton—certainly a close following of this valuation.

In this way it was taken to be demonstrated that the ores raised in Gilpin county were worth by average:—

Milling ore	$32 97	per ton.
Smelting ore	5 00	" "
Value of ore as raised	$37 97	" "

Fourth.—Loss by Milling.—This was and is yet the problem, and one found to be difficult to solve satisfactorily. Every interest engaged in the work of reduction, and those who furnished supplies, opposed anything that would endanger their calling or that tended to bring about a new method by new enterprise and new people. The average yield of the mills could be obtained readily, but no means were at hand to show why the yield was not double or where the waste occurred.

This had to be done by calculation, the data to be furnished incidentally through assays of tailings made—not to find the loss by milling, but for a guide as to what should or should not be reworked. The whole of these assays were taken, therefore, as the basis for a calculation to show the loss, and for this purpose an estimate had to be made of the relation between the tailings and the original ore milled. The best judgment on this subject allowed forty per cent. of the ore to have been carried off in the stream, leaving in the ordinary tailings-pile sixty per cent. of the original ore.

By calculation, then, it appeared that tailings averaging $23.15 per ton represented $13.89 to the ton of original ore milled. But the forty per cent. had also to be considered, since the float metal went with it and consisted of gold and its alloyage, and also the silver not alloyed,—the sulphide. The very low average of ten per cent. was adopted for the gold.*

* The loss of gold is positive, and amounts to $5.89 per ton. Estimating only ten per cent. loss by float there remains too much ($4.00) to be lost in buddling. Undoubtedly, the loss is more equally divided between the two sources of waste—the mill and the buddle.

It also required a settling of the relation of silver to gold in the ores. It was ascertained, and so settled at that time, that the mill bullion held an alloyage of about $20 in silver to $100 in gold. The work of eight years since has confirmed this figure as a close approximation. If, now, the assays of mill ore show only this relation then the silver must exist only as an alloy. But it was found that in mill ore proper this relation was as $77.65 instead of $20 in silver to $100 in gold, or $57.65 greater than the bullion alloyage. Hence silver existed in the mill ore in two conditions, as alloy and as an ore of silver, the latter not amalgable. Here, again, resort was had to reduction of this large difference. It was found that smelting ore carried less silver, by assay, than did the mill ore. Hence assays of smelting ore were added and the relation fixed at $57.58 to the $100 of gold. This reduction was a concession to prejudice and against fact.

With these elements it was then possible to show the value of the loss in gold and silver. This was found to be $22.09 per ton when the tailings were not reworked and $16.93 per ton when they were reworked and under the best conditions of milling.

Proof of Correct Valuation.—The working cost of milling and mining in 1872 was from $12.00 to $15.00 per ton. Mr Reichenecker closely calculated it at $11.01 per ton. Assuming his figures, we have the value of mill ore by adding loss to cost of working, viz:—

First.—By mill loss and cost of working.

Loss by mill ($10.88 saved from $32.97)	$22 09	per ton.
Cost of mining and milling	11 01	" "
Value of ore as raised	$33 10	" "
Value by assay averages	32 97	" "
Difference only	$0 13	" "

In this calculation there is no margin for profit by the mill, a usual result at that time,* the only profit in such case arising from the smelting ore.

But when the tailings are saved and reworked the loss is lessened and the calculation appears as follows:—

Loss by milling ($10.88+$5.16, saved from $32.97)		$16 93 per ton.
Working cost	$11 01 per ton.	
Profit saved by reworking	5 16 " "	
		16 17 " "
Value of ore as raised		$33 10 " "

*See Note No. 22.

The variance of the estimates is only $0.13 per ton. The mill ore would have to be worth $32.97 to pay expenses, unless the tailings were reworked. Mr. Reichenecker claimed $27.75 to be needed to pay expenses and fill the loss in working.* His low estimate of the sulphide of silver (or rather not estimating it at all, in this instance) accounts for the difference in his valuation. Adding for this sulphide, there would be the same close agreement arrived at in this respect.

Second.—By adding yield to loss.

Mill-men claim a saving up to seventy-five per cent.; then if—

50	per cent.	is saved,	no	float	loss,	ore worth		$29 23
"	"	"	add	"	"	"		37 43
60	"	"	no	"	"	"		23 67
"	"	"	add	"	"	"		41 87
70	"	"	no	"	"	"		36 98
"	"	"	add	"	"	"		45 18
75	"	"	no	"	"	"		38 62
"	"	"	add	"	"	"		46 82

And the yield would be—

At 50	per	cent. saving	$16 34	per ton.
" 60	"	"	19 78	"
" 70	"	"	23 08	"
" 75	"	"	24 73	"

But the yield for the past eight years has averaged only *$9.30 per ton by the mill.*

Either the tailings are worthless and there is no float loss, or the claim of close working by the mill is groundless.

Two facts are incontestible:—(1) The assay of ore and tailings are sufficient and indisputable; (2) The loss by float is incontestible, though not so easy of an exact estimate; hence Colorado's best ores *either must be poor* when the claimed close working produces only $9.30 per ton; or, Colorado milling ores, if profitable to work, *must be worth over $30 per ton* in gold and silver, of which between fifty and sixty per cent. is lost by the float and the reworking of the tailings by the mill and its attachments, under the most favorable conditions.

Unless the rich ores in Gilpin county have entirely disappeared since 1872 the waste in working has not been materially lessened, although with lower wages poorer ores may now be manipulated at a profit by careful and frugal management.

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*Mr. Reichenecker did not estimate for the incontestible loss of gold and the sulphide of silver in the flow of the mill. See Appendix, page 82.

Artice V.

Approximate Statement of the Value of the Production of Gold in the Principal Gold-Producing Countries (Prof. Blake, 1867).

COUNTRIES.	Value of Production	Totals.	Ratio per cent.
NORTH AMERICA.			
United States.—California	$25,000,000		
Nevada	6,000,000		
Oregon and Washington	3,000,000		
Idaho	5,000,000		
Montana	12,000,000		
Arizona	500,000		
New Mexico	300,000		
Colorado	2,000,000		
Utah, Appalachians, and other sources (estimated)	2,700,000		
		$56,500,000	43.23
British Possessions.—British Columbia (estimated for 1867)	$2,000,000		
Canada and Nova Scotia ($551,660)	560,000		
		2,560,000	1.96
Mexico (estimated)	$1,000,000		
		1,000,000	.76
CENTRAL AMERICA, SOUTH AMERICA, AUSTRALIA, AND NEW ZEALAND.			
South America.—Brazil (estimate, based partly on returns for 1866)	$1,000,000		
Chili (estimated, in part)	500,000		
Bolivia (estimated 1600 lbs. Troy) about	300,000		
Peru (estimated 2400 lbs. Troy) about	500,000		
Central America.—Venezuela, New Grenada, Central America, Cuba, and San Domingo (estimated)	3,000,000		
		5,300,000	4.05
Australia.—Victoria (1,392,336 oz. in 1867)	$26,510,000		
New South Wales (estimate based on reported production of 235,893 ozs. in 1866)	4,500,000		
South Australia (estimate based on returns for 1860)	140,000		
Queensland (1866), about	400,000		
		31,550,000	24.14
New Zealand.—(1864) $9,000,000. Estimated for 1867)		6,000,000	4.59
EUROPE, ASIA, AFRICA.			
Russia (estimate based on average of four years—1859 to 1864)		15,500,000	11.87
Austria (1865)	$1,175,000		
Spain (estimated)	8,000		
Italy (1866)	95,000		
*France (in 1846 about $9000)	80,000		
Great Britain (about)	12,000		
Africa (estimated)	900,000		
		2,270,000	1.74
Borneo and East Indies (estimated)		5,000,000	3.83
China, Japan, Central Asia, Roumania, and other unenumerated sources (estimated)		5,000,000	3.83
Total		$130,680,000	100.00

* In part from jewelers' sweepings and refuse materials.

NOTES.

No. 1.

DURING 1863–'65 there were one hundred and ninety-five companies organized in the east, one hundred and twenty-one of which were located in New York city; of these, one hundred and forty-two companies had a capital of $126,951,420. The aggregate reached some $160,000,00 (the capital of some omitted in the list). From fifteen to twenty per cent. of this nominal capital was paid up and expended in purchase, in contracts for machinery, in transportation, construction, and development. By 1866 nearly all of these organizations had ceased active operation. Some had failed, all were discouraged. The mills, costing large sums of money and freighted at $600 per ton (thirty cents per pound), had failed to treat the sulphides profitably.

No. 2.

HEIGHT OF OUTCROPPING.—The highest underground and hydraulic mines in the world are those of the Little Annie and Summit, Rio Grande county, Colorado, eleven thousand and twelve thousand feet, respectively, above the level of the sea.

No. 3.

NUGGETS.—The largest known was found in California and weighed one hundred and thirty-four pounds seven ounces;

another weighing twenty-seven and a-half pounds. One found near Miash, in the Ural Mountains, weighed ninety-six pounds. —*Prof. Blake.*

List of Nuggets.

1730.	La Paz, Peru,	60 lbs. Troy.
1838.	Cabarrus County, N. C.	28 lbs. "
(?)	Reid Mine, N. C.	80 lbs. "
1842.	Ural Mountains	97 lbs. "
(?)	Australia	146 lbs. 3 dwts.
1851.	"	112 lbs.
1851.	"	106 lbs.
(?)	Australia (the Sara sands)	223 lbs. 4 ozs.
1853.	Ballarat	168 lbs.
(?)	California	160 lbs.
1869.	Australia	112 lbs.
1869.	Sierra County, California	106 lbs.

(*Raymond's Rep.*, 1872, *page* 346.)

(There seems to be much variance in statements with respect to size and finding of nuggets.)

No. 4.

Auriferous Sulphides.—"In Russian solid-rock mines gold is most plentiful where the drift is most largely charged with iron."

"In Virginia, the gold is most plentiful in the brown ore and in the joints and cavities of the bed. As in Brazil, the gold is most plentiful when the iron ore and quartz are combined and most scarce when either is alone."

"In Nova Scotia, veins bearing gold in which free gold is disseminated contain copper pyrites, with occasionally galena, silver glance, metallic silver, and iron pyrites."

At Morro Velho, "experience shows that a mixture of iron pyrites and quartz makes the best matrix for gold, the metal being abundant where they are pretty equally mixed, but scarce where either prevails separately."

"In Australia, the gold is usually associated with iron pyrites and titaniferous iron; the productiveness of the quartz or otherwise appears to depend chiefly on the age of the quartz, and, as in Brazil, in the presence of iron pyrites." "Besides occurring associated with pyrites in granite rocks gold also occurs disseminated in pyritous diorites, in pyritous felsites, and also in pyritous quartz and calcspar veins, usually well defined, wide, and persistent."

"In quartz it is most abundant where iron pyrites, titaniferous iron, and other ores of iron prevail."—*Davies.*

"Gold is generally found intimately associated with the sulphides of iron, being aggregated along with them and in auriferous strata, the iron ore, whether collected in quartz-veins, or scattered in detached crystals through the rock, is seldom found without gold. This intimate association also exists in the case of recent pyrites formed in auriferous drifts which invariably contain metallic gold incorporated with the sulphide of iron.

"In localities where the sulphides of iron are not plentiful or where the decomposition of the rock has been so great as to allow a considerable portion of these auriferous sulphides to be removed and aggregated with the quartz, gold-bearing rock will be found below the water-line, irrespective of the depth. When the sulphides in the rock are completely decomposed, as they are found above the water-line and near the surface, the gold thus liberated is then in a condition to be acted upon by other agents, and it is probable that nearly the whole of it has been accumulated in the veins, forming the rich surface deposits so frequently met with. The rich casing or layer of rich auriferous slate running by the side of the quartz, which is occasionally found above the water-line, changes below this point into a layer of slate full of auriferous pyrites, and an extention of this action to the boundary rocks will account for the surface deposits."—*Sir R. Murchison.*

No. 5.

Depth of Mines.—Good mining results have thus far been attained to a depth of two thousand feet. "In Victoria, Australia, about thirty mines have reached a depth ranging from one thousand feet to eighteen hundred feet."

The Hayward Mine, California, is down below two thousand feet.

No. 6.

Metallic Ores occur in lodes in a variety of ways: (1) as sprinkled in the midst of solid quartz; (2) filling up as a solid body the whole of the crack; (3) forming nests and pockets connected by strings; (4) forming a considerable deposit on one side of the lode, and when discontinued on one side commencing on the other; (5) irregularly dotted over the whole width of the lode; (6) in regular layers, which, from the centre of the lode to the sides, answer each to each, and, when space permits between them, crystallizing into their beautiful characteristic forms.—*Davies.*

No. 7.

Solid Metallic Lodes.—Where the ore is very pure, filling the whole chasm, and hardly separable from the walls of the lode,—a sublimated origin seems probable. Where, again, the metallic matter occurs in parallel layers, the result may have been occasioned by gradual condensation from ascending vapors. Where, however, such layers are loose in texture and the inclosing mineral coarse, the result may have arisen from infiltration. Probably in the same lode each of the modes of operation may have been employed, each in its turn contributing its quota to the final result.—*Davies.*

No. 8.

Width of Some Lodes.

Width of Fissure or Crevice in Colorado.—The territorial assay records of one hundred and eight statements officially made as to width of vein (from which assay samples were taken) vary from one foot to eight feet, and average slightly over four feet. The average width of really productive lodes may be set down at three feet, all subject to contractions and expansions, sometimes pinching to a thread, at other places bulging into enormous bunches.

The Mother Lode, the great vein of California,—estimated length from eighty to one hundred miles,—varies in width from a few inches to thirty feet.

California Mines.

(Blake.)

Long Tom Mine, from three to eight feet wide.
Mamoth Lode, from three to eight feet wide.
Princeton, from two feet to seven feet wide.
Raw Hide Ranch Mine, ten feet wide.
Hayward Mine, from eighteen to twenty feet wide.
Jefferson Mine, six feet wide.
Sierra Buttes, usual thickness from six, eight, to twelve feet, sometimes from sixteen to thirty feet.
Independence Mine, twenty feet wide for about three hundred feet.

No. 9.

Yield of Some Veins.

(Blake.)

Long Tom Mine, California, yield average $20,000 per month; average expense $3000 per month.

The Comstock Lode.—Production from 1860 to 1875, $199,824,364, of which $80,000,000 in gold.

Mammoth Lode, Kern river, California, yielded $1,000,000.

Princeton Vein, California, aggregate yield $3,000,000.

Soulsby Mine yielded $400,000 in three years.

Keystone Mine, California, from 1851 to 1867, $1,100,000.

Hayward Mine in 1866 yielded $450,000; gross from opening to 1867, $3,000,000.

Eureka, California, gross yield in 1866, $596,053.

North Star, California, over $500,000 realized in five years.

Ophir Mine, California, $1,000,000 from 1852 to 1864.

Gold Hill, California, $960,000 in three years.

Nevada County Assessors' Report (1865).—Yield of nineteen mines, $2,227,000.

Jefferson Mine, California, $13,500 per month; expenses $4500.

Sierra Buttes Mine, California, yield from 1861 to 1866, $1,345,000; expenses $460,000; profits $884,400.

Gold Hill, North Carolina, yield $2,000,000.

Morro Velho, Brazil, since 1842 up to 1867, aggregate profits $5,000,000; total value extracted, $14,512,400 from 1,769,050 tons.

Imperial Brazilian Mine, from 1826 to 1856, yield $7,337,240.

COLORADO (FOSSETT).

Black Hawk and Briggs Mine, Colorado. In 1867, product $279,647; two hundred and forty feet of Briggs' mine yielded $534,615; monthly yield about $13,000 average.

In 1875 the *Gregory* yielded $225,934; yield of *Gregory Lode* from discovery to 1879, $6,830,354.

Yield of one thousand and forty feet *Briggs and Gregory*, $4,205,000. The *Bobtail*, yield $4,500,000. Yield of the *Consolidated Bobtail*, 1878, $424,158; in 1879, $600,000.

No. 10.

YIELD OF SOME PLACER MINES,

(BLAKE.)

Estimated yield of one mile of *Blue Lead*, $5,095,000.

Blue Gravel Company in twenty-three months produced $642,860.

Cement.—Enormous accumulations of sand, clay, gravel, and sometimes tufa and lava, thoroughly cemented together, with river-worn and rounded boulders and stones, so as to form a solid conglomerate—a pudding stone, the "cement" of the miners.

The gold washings of John Day river, Oregon, in 1864 yielded $1,500,000, and yield of the State, $2,000,000.

The gold product of Montana up to 1868, nearly all placer gold,—$72,000,000.

Smartsville, Yuba County.—Quantity of ground washed, twenty-five million cubic yards; product, $10,000,000. Gravel remaining in place, one hundred million cubic yards.

No. 11.

Average Yield in California.

Data for a clear estimate are scarce, principally from two causes—overstatement when ores are rich, reticence when working ores of low grade.

CALIFORNIA.—Nearly five hundred thousand tons yielded $23.87 per ton average from mines located in twelve counties, including the best and very few of the lower grade. Gathering from scrap-statements made of numerous mines over the State, the reports running through six or seven years, a million of tons may be aggregated which will show an average of about $18.00 per ton. But there are many mines worked the output of which do not yield beyond $6.00, $10.00, or $12.00 per ton. No data for these are given, or so few that no satisfactory

average can be made. It is, however, entirely clear that the ores milled in California do not yield an average beyond $15.00 per ton, when the whole field is considered.

No. 12.

Average Value of Auriferous Ores.

The average per ton yield of rock in California, Colorado, Australia, and Brazil ranges about $15 and this figure may be taken as the standard. Enough of proof has been developed to average the loss, by working, to be thirty-three per cent. In other words, the standard auriferous quartz of the world may be averaged at $20 per ton.

Del Mar credits California with production of $1,100,000,-000 bullion—one-fifth from quartz, then 14,600,000 tons of quartz milled—Australia, $1,200,000,000—one-fourth from quartz, then 20,000,000 tons milled—Brazil $900,000,000, —one-tenth from quartz, then 6,000,000 tons milled. Colorado has produced $75,000,000—say one-half from auriferous rock, then 2,500,000 tons milled. Total 43,100,000 tons at $15=$646,500,000, waste $215,500,000.

No. 13.

COLORADO.—The average yield in this State, represented by Gilpin county, is now well settled to be about $9.30 by mill and $5.20 by smelting, say $15.00 per ton. The data given in Fossett's Guide is sufficiently positive to permit of no material error on this point.

The boast of Colorado has been that her ores were the richest, on the average, in the world. This boast is idle, if the waste is such as claimed by mill-men. The yield of every other important mining district in the world equals the yield of Colorado per the ton. And it is to the discredit of that State, if the boast is true, since elsewhere this general average of $15.00 per ton is the estimate of all ores, poor and rich; whereas the actual yield of $15.00 per ton in Colorado is the product of her best mines. The lower-grade rock in Col-

orado is not worked, and does not enter into the average, as is the case with California, Australia, and other areas.

Either this boast of close work must be given up or the waste must be acknowledged. The ores of Gilpin county are worth from $30.00 to $40.00 per ton as mined. The waste is between $15.00 and $40.00 per ton.

No. 14.

Number of Stamps.

California had in 1870 about five thousand stamps in four hundred and ten mills, and also four hundred and twenty arastras. The investment of capital is shown at the rate of $950 per stamp=$4,800,000; including the arastras, say, $5,500,000 cost of plant. The capacity rated at one ton for each stamp would be one million five hundred thousand tons for three hundred working days of the year, and for the arastras, at two tons daily, two hundred and fifty thousand more,=one million seven hundred and fifty thousand tons annually. Doubtless the work realized equals eight hundred thousand to one million tons per annum.

Colorado, it is said, has about eight hundred stamps actively working in Gilpin county, and from thirty to forty idle mills. The mills had 1597 in '72. Cost of establishments rated about same as in California, viz., $1000 per stamp. The work of a stamp, three-quarters of a ton in twenty-four hours.

The number of stamps in all other gold-mining areas of the United States may be estimated at from one to two thousand.

Should more attention have been given to such statistics in the recent census (1880) than was given in 1870, the aggregate of stamps in the whole country, intended for working gold ores, will be found to reach from eight thousand to ten thousand.

No. 15.

COST OF MINING, MILLING, WAGES, &c.

California.—Tabulated statements made (Raymond's Reports) of the operative costs at some forty and more quartz establishments, employing two thousand four hundred and forty men above and below ground, present data for the following averages:—

Mining, per ton	$5 75
Milling, "	2 00
Total cost of handling one ton	$7 75

Wages, $2.80 per day.

The labor of one man handles about one hundred and seventy-two and a-half tons yearly, hence the manual labor cost of one ton is $4.87, and cost of power, supplies, &c., $2.88 per ton. It is to be remarked that the above includes the best paying mines and but few of the concerns working low-grade ores. The cost of mining indicates narrowness of vein or a great surplus of worthless rock in the mines worked.

No. 16.

Colorado.—Statements are made in Mr. Fossett's book which show mining as low as $1.90 per ton. Doubtless a fair average cost would be from $3.50 to $4.00 per ton. Milling about $2.00 per ton. Wages from $2.00 to $2.50 per day.

The *Bobtail Consolidated*, in 1875–78, expended for mining and milling, including all costs but smelting, $10.12 per ton, rating the cord at seven tons. Another representative concern, all costs but smelting, $10.48 per ton.

Smelting cost ranges from $1.50 to $2.50 per ton. For instance, ore holding $120.00 gold, $30.00 silver, and $10.00 in

copper or lead=$160.00 per ton, is sold to smelters for $110.00 per ton, that is $50.00 per ton smelting cost. The smelting ore averages about five per cent., or five tons in the one hundred tons. (In 1877–'78, two hundred and ninety-three thousand two hundred tons furnished thirteen thousand two hundred tons smelting ore, or four and five-sevenths per cent.) Taking five per cent., the above cost would rate at $2.50 per ton on all the ore treated, ninety-five tons by mill and five tons by smelting in the one hundred tons.

Cost per ton of Ore treated in Colorado.

Mining average	$3 50	per ton.
Milling "	2 00	"
Smelting "	2 50	"
Total	$8 00	per ton.

Doubtless this average is overrun more frequently than otherwise, as for instance in the case of the *Bobtail Consolidated*, &c.

No. 17.

Gold Dust—Float Gold.—A carpet, down for five years in the San Francisco mint, was taken up, cut into small pieces, and burned in pans. The ashes yielded $2500.

No 18.

Waste of Gold in California.—"As far as California is concerned I am satisfied that not more than forty per cent. of her gold is extracted. The fact is, as before expressed, we are not working for gold or silver, but to crush rock.—PAUL, *in Raymond's Report*, 1872.

No. 19.

" Our present general system of gold mining is based upon the idea that gold is mainly course, while examination will

show that the high percentage is in atoms finer than flour itself. In my experiments, gold has been taken up so fine that in distilled water it would not precipitate in less than from five to ten minutes. Can you save gold of this kind by running water down stream? Again, can you obtain the gold of this fineness without minute reduction? Therein lies the secret of high assays before working and small returns after."
—PAUL, *in Raymond's Report*, 1872.

No. 20.

CHARGES FOR SMELTING.

At San Francisco the charge is from fifty dollars to one hundred dollars (gold) per ton for smelting gold and silver ores.

At Reno, for ores assaying $80, the charge is $46; for $100, the charge is $50; for $200, $70, and for ores assaying $500, the charge is $105 per ton.

At Omaha.—Treat ores for one hundred dollars per ton, and guarantee one hundred per cent. of the gold and ninety-five per cent. of the silver.

At Newark, N. J., the charge is fifty dollars per ton for the lowest grade of ore, advancing in price to over one hundred dollars per ton.

Boston and Colorado Smelting Company treat $50, $100, and $150 ores at a cost to the miner of $35, $40, and $45, respectively—prorated for intermediate values. (These prices are now somewhat reduced.)

(*Raymond's Report*, 1872.)

No. 21.

VALUE OF RETORT BULLION IN COLORADO.—The banks purchase the mill retorts of bullion, the value of which is estimated on the alloyage of silver contained. The average alloyage of gold, from all the chief mines, appears to be seven

hundred and eighty-seven gold, to one hundred and ninety-eight or two hundred in silver, balance copper (standard 1000); average value per ounce sixteen dollars. Practically, one hundred dollars in gold bullion carry from twenty dollars to twenty-one dollars in silver as an alloy.

No. 22.

Battery Amalgamation.—The following is one of the very best and most characteristic examples of stamp-mill work or battery amalgamation. An actual working exhibit.

Treated by stamp-mill	850.00 tons.
Sold to smelting works	13.27 "
	863.27 tons.

Mill ore assayed per ton.....Gold, $25 13, Silver, $1 94=$27	07
Smelting ore assayed per ton..... " 131 21, " 16 22=147	43
Assay value of all ore raised, per ton	28 92
Average yield per ton in currency, mill ore	12 68
" " " " smelters' ore	110 07
" " " " all ore raised	14 17
Gold, mill ore yield	40 per cent.
The whole value of the ore	$24,965 76
The absolute loss by milling	12,693 38

A Working Test by Mill.—A well-authenticated statement, made in 1870, by owner—ore treated in a mill doing custom work—is the following. Amount of ore, 140 tons:—

Mill yield from battery and plates, 80½ ozs., @ $16.00...........$1,288 00

Tailings stopped and assayed—

13½ tons, first tailings 67½ ozs. gold (assay)	1,080 00
13½ " " 148½ ozs. silver (assay) @ $1.30	193 00
45 " second tailings 157½ ozs. gold (assay)	2,520 00
45 " " 405 ozs. silver (assay)	526 50
Value of ore (no estimate for float loss)	$5,607 50
" " per ton	40 05
Product by mill per ton	9 20

Less than twenty-four per cent. saved by the mill.

The owner attended to stopping tailings himself. A like quantity of ore from same mine treated at mill, and no stopping of tailings, brought the owner a loss on this $40 ore:—

A small lot of 10½ tons, worth by assay	$243 00
Treated in mill yielded	126 00
Loss by mill in the tailings	$117 00
The tailings, when buddled, produced (assay)	22 50

Not quite twenty per cent. saved by reworking or buddling the tailings.

No. 23.

"DRIFT IN RELATION TO GOLD.—There has been throughout all geological time a progressive concentration of gold, as well as many other metals, in a more available form: (1) It was first *disseminated* in excessively small quantities, too small to be detected, *through the slates*, derived doubtless from the sea, in the waters of which it is detectable in very small quantities. (2) After the upheaval, crumpling, metamorphism, and fissuring of these slates, the gold was dissolved and accumulated along with silica, and metallic sulphides, in these fissures, as auriferous veins. (3) Atmospheric agencies acting on these outcropping-veins dissolved away the sulphides, and left the gold in a still more available form along the backs of the veins. (4)Then came the ice-sheet and the glaciers of the Quaternary, like a plough, cutting away the backs of the quartz veins, together with the containing slates, and, like a mill, grinding all to gravel, and heaping it away in moraines. Some of the placer mines are in these moraines, but mostly the gold has been subjected to still another process. (5) Lastly, in the Champlain epoch, the river floods washed these moraine-heaps down the rivers, sorting them and depositing where the velocity of the current diminished. These river gravels, thus sorted,

cradled, *panned* by the action of currents, and therefore with the coarse gold near the bottom and high up the gulches, constitute the richest placer mines."

"Gold originally existed in quartz veins usually associated with metallic sulphides, particularly the *sulphide of iron* (pyrites). If the pyrites be dissolved in nitric acid the gold is left as minute threads and crystals. Evidently, therefore, it exists in minute threads and crystals scattered through the pyrites. Now, when such a vein is exposed to meteoric agencies the pyrites are oxidized, partly as soluble sulphate and carried away, and partly as insoluble reddish peroxide of iron which remains. The quartz-vein stone is, therefore, left in a honey-comb condition by the removal of the pyrites and more commonly stained of a rusty color by the peroxide. Among the cells of this rusty cellular quartz the gold is found in minute, sharp grains, evidently left by the removal of the pyrites. Hence in an auriferous quartz-vein, along the outcrop to a depth of thirty to sixty feet gold is found *free* in small grains among the cellular quartz; but below the reach of these agencies it is enclosed in the undecomposed pyrites."

"PLACER MINES.—If a mountain-slope, along which outcrop auriferous quartz-veins, be subjected to powerful erosion by water-currents, then in the stream-beds will be found gravel drifts, composed partly of the country rock and partly of the quartz-vein stone. Among the gravel will be found particles of gold, washed out from the upper parts of the veins. By the sorting power of water the heavy gold particles are apt to accumulate mostly near the bed of the gravel-deposit (bedrock). These gravel-deposits are the *placers*. In these, the gold particles, like the stone-fragments, are always *rounded* and *worn* by attrition."—*Le Conte.*

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